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MEDICAL AND OTHER CONDITIONS IN SOVIET RUSSIA

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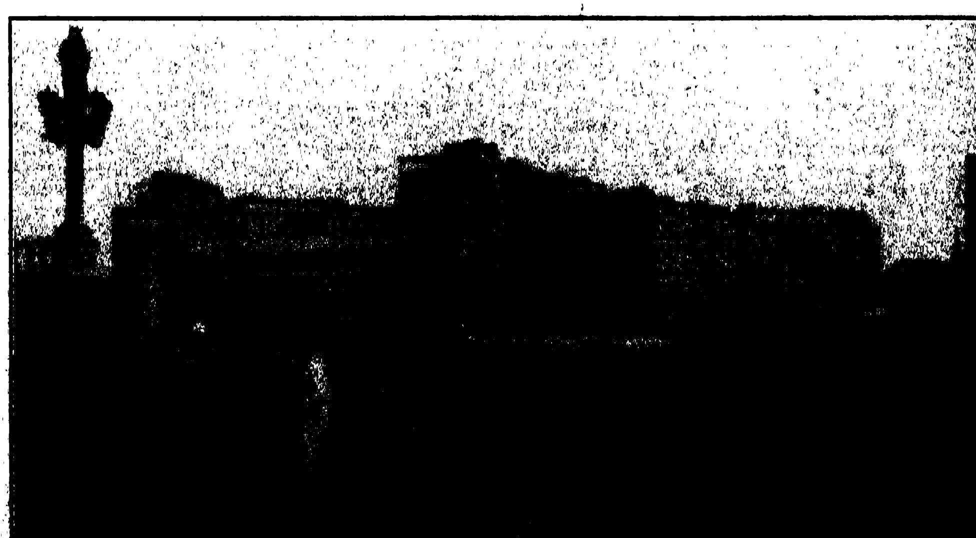
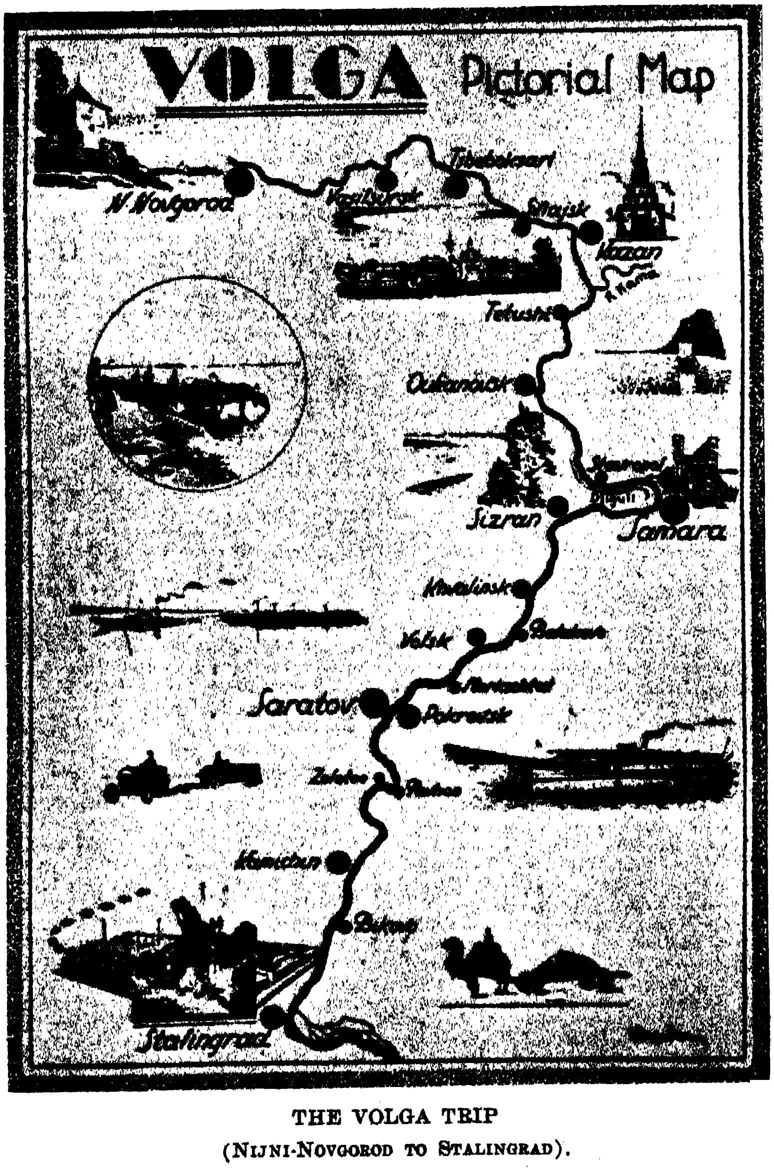
IN a recent volume, "The History of the Russian Revolution," Leon Trotzky, now in exile, points out that backward countries, although compelled to follow after advanced countries, do not take things in the same order. Rather it is a privilege of historic backwardness to permit, or rather to compel, the adoption of whatever is ready in advance of any specified date, skipping a whole series of intermediate stages, the development as a whole thus acquiring a complex, combined character. Though this author was thinking chiefly of political and economic development, the principle he refers to has certainly been strikingly illustrated in the development of medical activities in Russia since the Bolshevik revolution. There has been not only a great leap forward in the adoption of many of the better measures of public health worked out in more advanced countries, but Soviet Russia, through the leadership of its first commissar of health, Dr. N. A. Semashko, has initiated a number of public-health measures that are unique and make a certain appeal to the countries in which cultural develop-



NEW OFFICE BUILDINGS FOR THE SOVIET BUREAUCRACY IN MOSCOW



THE VOLGA TRIP
(NIJNI-NOVGOROD TO STALINGRAD).

ment in general has reached a far higher stage than in Russia.

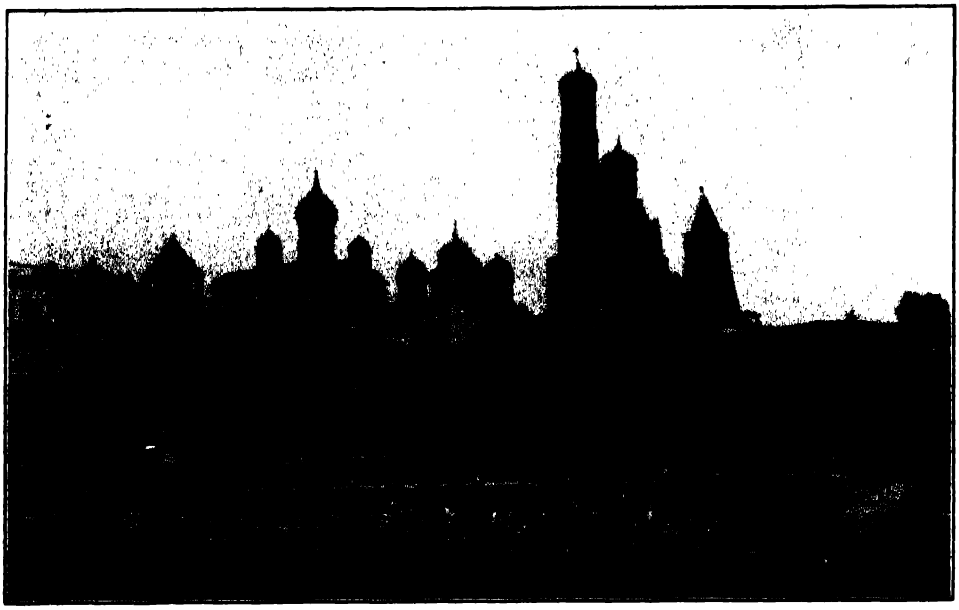
During the past summer, my wife and I flew from Berlin to Moscow and joined a party of eight, under the leadership of Dr. David Ostrinsky, of New York, for a twenty-five day tour through Soviet Russia. In this article I shall mention some of the impressions we formed of medical and other conditions now prevailing in Soviet Russia. I was permitted to take several hundred photographs, and from these I have selected a number that illustrate objectively some of the conditions as we ourselves saw them; from them, readers may form judgments for themselves regarding the appearances as seen through the eye of the camera.

Many of our friends were dubious as to the safety and the value of a trip to Soviet Russia at this time. Some of them even feared that we might be in danger of our lives, or that we would become ill because of food conditions and of the discomforts of traveling; others were of the opinion that the trip would scarcely be worth while, since they believed that we would be "led about by the nose," would be shown only things that the authorities were willing for us to see and would not be permitted to visit persons or places except when accompanied by official guides and under the surveillance of the much-dreaded Secret Police (G. O. P.)

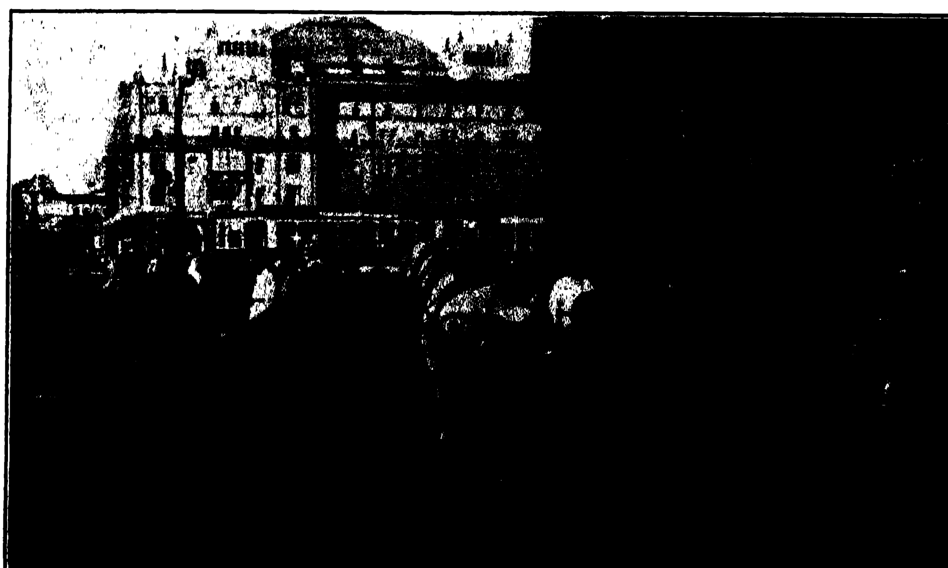
On reaching Russia, however, we discovered that these ideas of danger and of limitation had been greatly exaggerated. We were everywhere treated with courtesy and consideration. We were allowed to move about freely and in no instance were we prevented from visiting persons or institutions that interested us. If we were under close supervision, this was neither obvious nor obtrusive. I was permitted, as I have said, to take photographs freely, the only interdiction being photography of railway stations, fortresses and the Red Army; the authorities retain the privilege, however, of inspecting the developed films before they are taken out of the country.

Most tourists, it is true, are accompanied everywhere by official guides and interpreters, since very few of the foreigners entering the country speak Russian. We were fortunate in having most intelligent guides, who were tireless in helping us to make the most of our trip. My wife and I spoke no Russian, but we both speak some German and a little French, and I visited a number of university professors, medical clinics, research institutes and the Academy of Sciences entirely unattended. Since it was possible, on these visits, to converse in English, German or French, I got, I believe, a very fair impression of the medical and scientific situation as it exists, especially in Moscow, Leningrad and Odessa. Medicine is a kind of free-masonry and medical men are prone to talk with one another quite freely; the Russian physicians and scientists with whom I conversed seemed to me to be entirely frank in their discussion of conditions. Many of these were not members of the Communist Party. Indeed, some of them had been strongly opposed to the Revolution, though they have, since its victory, adapted themselves to the new régime. My wife and I had the privilege of dining with one of the professors of medicine and his family in Moscow, and thus got a glimpse of the actual home life of an important medical man. With the Reverend Dr. Lindsay, of Brookline, Massachusetts, I visited in the suburbs of Moscow a young worker who, with his wife and child, occupied a one-room apartment in a three-family cottage; we took afternoon tea and discussed their mode of life with them. We had many other opportunities freely to examine, without supervision, certain situations in which I was interested.

The food supplied, though sometimes



THE KREMLIN IN MOSCOW



A DROSCHKE FOR HIRE (MOSCOW)

monotonous and not always attractively served, was sufficient. A professor from the University of Pennsylvania told me that he had been a chronic dyspeptic all his life, but that during his trip through Russia he had been entirely free from symptoms of indigestion! The circumstances of travel, though, of course, very different from those to which we are accustomed in America, were everywhere tolerable. As a matter of fact, we gained the impression that the authorities of Soviet Russia welcome American tourists and try to make their sojourn in the country as comfortable and as interesting as possible for two reasons: (1) In the absence of diplomatic recognition, they feel that Americans have very wrong impressions of the conditions that exist, and (2) they hope that tourists will, while in the country, spend some of their foreign money in addition to the actual cost of the trip paid before entering the country, since the authorities are very desirous of acquiring *valuta*, with which they may make purchases of machinery and other supplies from outside and may pay salaries to the foreign experts now at work in helping them to develop their natural resources.

Our tour included approximately a week in Moscow, a few days in Leningrad, a visit to Nijni-Novgorod, a four-day trip down the Volga River to Stalingrad, a day in Rostov, and a few days in Sochi on the Black Sea, in the Crimea, and in Odessa, after which we returned to Europe by way of Poland and Vienna.

RUSSIAN GUIDES

Though they do not use the terms "first, second and third class" for travel in Russia, one can travel by "category P, category W, or category T," which correspond to different prices and comforts. Our party chose category W, which gave us soft cars on the railway, whereas category P supplies international Pullmans where they are available, and category T means traveling "hard." On occasion, we found it desirable to pay a supplement in order, on

long journeys, to travel in international sleeping cars.

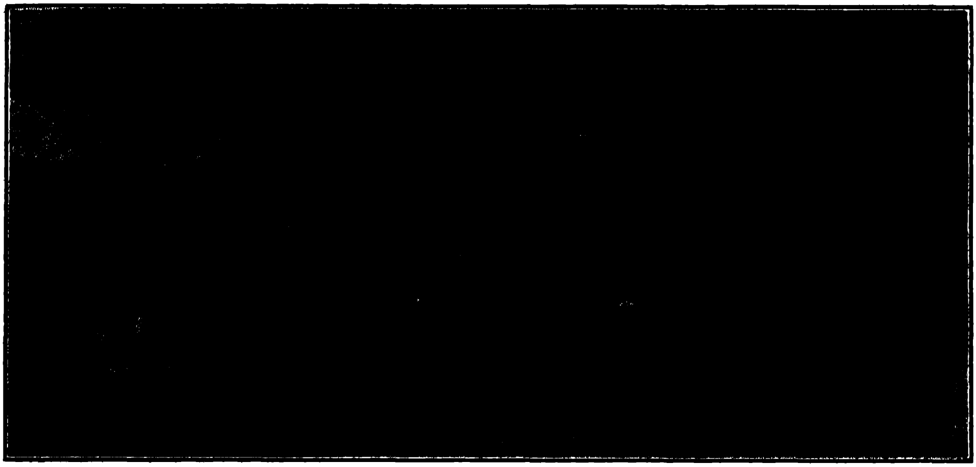
The most contradictory views exist among intelligent people in America as to the nature and outcome of the economic and social experiment now under trial in Soviet Russia. Among the several views expressed, there are four, as Brandt has pointed out, that seem to be more widely held.

In the first place, there are many who feel so certain that the Russian experiment is doomed to total failure and soon that they think any serious discussion of it merely futile; but it should be recalled that the Soviet government now in power has held office for nearly fifteen years, longer than any other cabinet in Europe, and we gained the impression that it is likely to remain in power for a long time, zigzagging so as to go now to the "right" and now to the "left," and making whatever compromises are necessary to hold the support of the masses. An American engineer who had been long in Russia told me that he considered the Soviet government the most stable in Europe at the present time.

A second view, held by some of those who sympathize warmly with the Soviet régime, sees Russia as a kind of earthly paradise in which there is plenty of good food, no unemployment and equality of wealth and opportunity for all. An actual visit to Russia ought to temper such a view, since, as I have said, the food is none too good and none too plentiful. Though great strides have been made toward equalizing opportunities, it is, as far as wealth is concerned, equality of impecuniosity that has thus far been achieved. That unemployment is, however, practically nonexistent must be admitted; and Soviet Russia, in this respect, is in marked contrast with the rest of the world in the present economic crisis.

A STREET SCENE IN MOSCOW

A third view that is widely held is that Russia, through alleged enforcement of labor, the Red army and restriction of expenditures to the development of its industry and natural resources, is becoming a definite economic

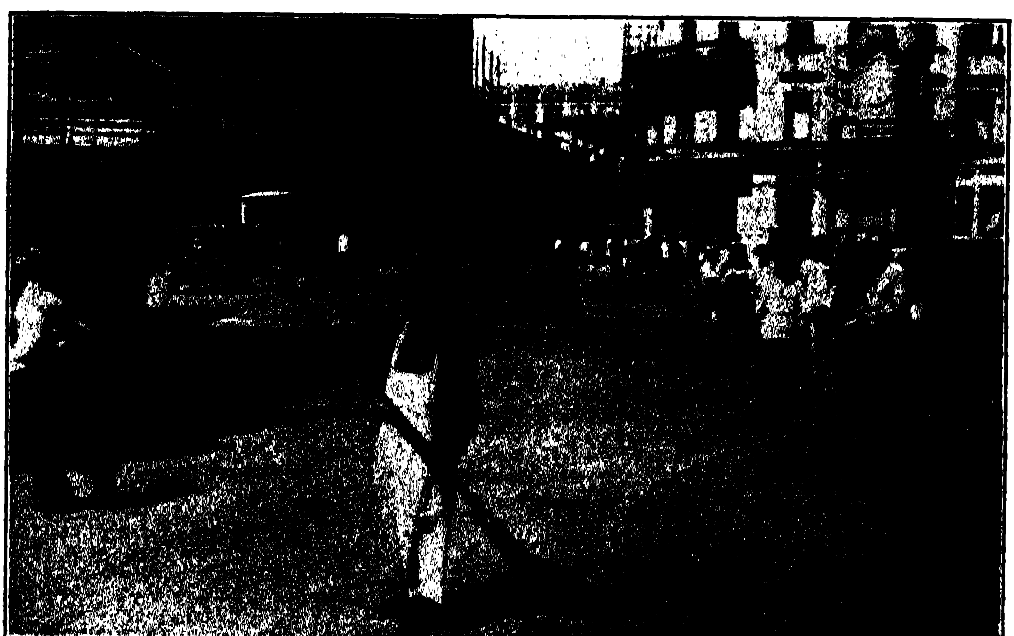


WAITING QUEUE IN FRONT OF A COOPERATIVE FOOD STORE

and military menace to the rest of the world. But those who hold this view seem to forget the very backward state of Russia, the distance she has to travel before catching up with the achievements of capitalistic countries, and the difficulties that must be overcome in changing an illiterate peasant population into an educated industrial people. During the revolution and the years that immediately followed, Russia lost many of her prominent business men, many of her engineers, many of her skilled workers and many of the intelligentsia, through death or emigration. She is making strong efforts to meet the situation by saving every kopeck possible for the development of great industrial plants and cooperative farms, and for the payment of experts and skilled workers imported from abroad; but even her leaders admit that she has poor transportation facilities, that there is much mismanagement, that there is still appalling waste, and that the quality of production is far from what is desired.

GIRLS SELLING FLOWERS IN MOSCOW

STREET SCENE IN MOSCOW
WITH VICTORY ARCH IN THE DISTANCE.



STREET SWEEPER IN MOSCOW

It looks as though it would require two or three generations, at least, to bring society and industry up to standards anything like those of the West. Communism has, temporarily they say, been given up for a kind of State Capitalism, with some small-scale private capitalism still permitted; they expect later on to pass from this through an ever-increasing socialistic régime to the ultimate goal of Communism. Meanwhile, there would seem to be very little menace to other countries, either from the economic or the military side. Russia does not want war; what she wants is to be left alone in order to develop. Nor has she, in my opinion, money to spend on propaganda for the fomentation of revolution in other countries, contrary to what is generally supposed.

A STREET SCENE IN MOSCOW

CROWD AROUND A MAN SELLING A FEW CUCUMBERS AND TOMATOES. NOTE THE COBBLE-STONE STREETS. SINCE OUR VISIT THE STREETS IN MOSCOW HAVE BEEN REPAVED.

A fourth view, attributed to Colonel Hugh L. Cooper, the distinguished American engineer who is supervising the building of the great dam upon the Dnieper River, which is to supply electrical power for the Ukraine, is believed by Mr. Brandt, of the *St. Louis Post Dispatch,* to be most in accord with the facts. Colonel Cooper, who has formed a close friendship with Stalin, is of the opinion that Stalin differs from Lenin in that he thinks the Soviet régime can succeed without world revolution and that her best course is to "cultivate her own garden" and to avoid stirring up revolution in other countries. If this attitude should be maintained by Stalin and his successors, Colonel Cooper believes that, through the development of the heavy industries and through intensive cultivation by State and cooperative farms, Russia will not only survive, but will gradually reach a much higher state of wealth and of culture. During the period of her development, however, and as conditions gradually improve, there will be an increasing demand for comforts and luxuries, which Russia, herself, will not be able to supply. She ought, therefore, to afford a vast market for Western Europe and for America for at least two or three generations. My own observations while in Soviet Russia made me agree with Mr. Brandt

that Colonel Cooper's view is more in accord with the situation than the other three views referred to. On talking with Mr. Walter Duranty, the correspondent of the *New York Times* in Moscow, I found that he also leaned to this opinion.

GENERAL CONDITIONS IN SOVIET RUSSIA

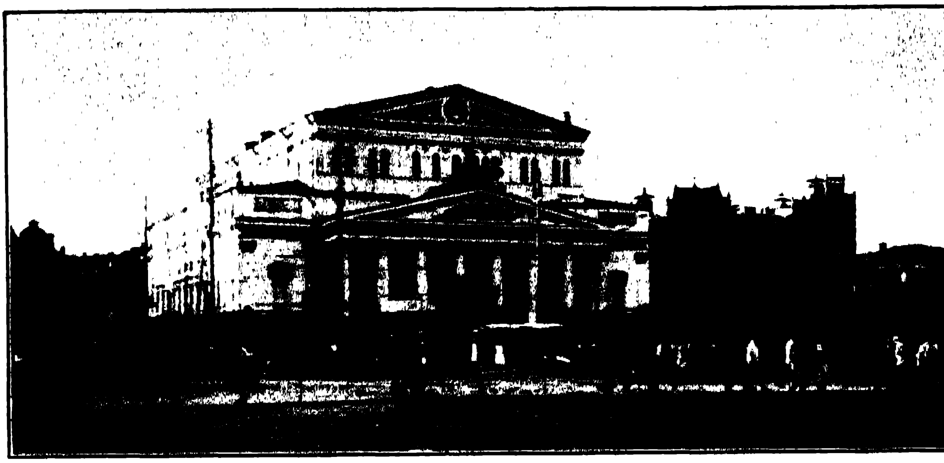
On entering Russia, one's attention is directed at first, of course, to the general situation—to the appearances of the streets, the shops and the people. The photographs that illustrate this article will give, perhaps, a better impression of these than any detailed description. One can not help but be struck by the primitive character of the pavements, the drab appearance of the streets, the emptiness of the shop windows, the long queues of people standing in the streets in front of cooperative stores, carrying their baskets for holding food rations, the crowded street cars, the aggregation of people in gossiping groups and the characteristic headwear and footwear. One sees very few horses and carriages and almost no automobiles, except the few that belong to officials and to the tourist agency. The Russians simply can't believe that we have twenty-six million private automobiles in use in the United States!

TRAVELING ACTORS FROM MOSCOW

MAKING THE ROUNDS OF THE COOPERATIVE FARMS AT HARVEST TIME.

A striking feature is the absence of class distinctions in the way of dress or bearing. The people look as though they all belong to one class (as theoretically they do). In hotels and restaurants, one is waited upon by men with rolled-up sleeves and turned-in shirts, or by men in blouses. The table-cloths sometimes show the spots of many preceding meals.

Women are on an equality with men, and the women, both married and single, are all at work as the men are, the married women leaving their young children in the factory *crèches* when they go to work. I may cite one interesting example of what this equality means. One day in Moscow, while seated in a street



GREAT ACADEMIC STATE THEATER IN MOSCOW

car, a young woman entered, and, as every seat had been taken, I rose and offered her my seat, which she declined. My companion, who knew Russia well, told me that I had "insulted" this young woman, that she was strong and well and, therefore, my "equal." Had she been a very old, feeble woman, or a young woman who was obviously sick, or pregnant, my offer would not have been regarded as insulting! I was told that a woman who is pregnant carries a pregnancy card and, on entering a street car in which no seat is available, the conductor on presentation of the card, arranges that she may have the privilege of

REGISTRY OFFICE

FOR MARRIAGES AND DIVORCES IN MOSCOW.

A WAIF GIRL

IN FRONT OF THE GRAND HOTEL IN MOSCOW. MOST OF THESE WAIFS ARE NOW HOUSED IN ORPHANAGES.

standing in one corner of the platform where she can support her back, or has a seat vacated for her.

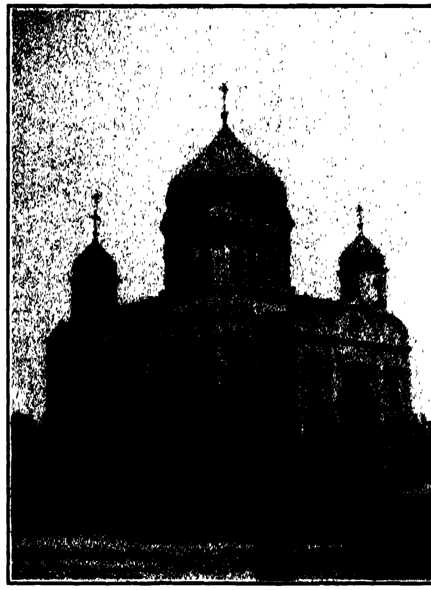
The art treasures of Russia are being preserved. Indeed, the great galleries, like the Hermitage in Leningrad, are more valuable now than before the revolution, since the private collections were confiscated and the best pictures put into the State galleries. Music and the theater are well supported, and workers in the factories are given tickets, either free or at reduced rates, for notable performances and concerts. During the summer, troops of actors from Moscow and Leningrad travel in box-cars through the country districts and give entertainment to the agricultural workers. Music sometimes has to take the place of good food; I remember particularly, while eating a rather bad dinner in one of the smaller cities, that we had the pleasure of listening to an excellent orchestra of eight pieces!

Marriage is made very easy; the two who desire to marry present their workers' cards at a registry office, pay a small fee and are recorded as man and wife, no religious ceremony being necessary. Divorces are equally easy when they are desired, but there are strict rules with

COMMUNITY SINGING IN MOSCOW

regard to making provision for the maintenance of the children of the divorced persons.

The Soviet authorities adhere to the doctrine of "dialectic materialism" and insist upon the teaching of this in all schools. Religion seems to be anathema to them, and the statement of Lenin that "religion is the opiate of the people" is often cited. The orthodox church in Czarist times was in close league with the Czaristic government and the aristocracy; it was functionally scarcely religion in the sense that we understand it. The people were, therefore, willing to see the religious organizations disappear along with the Czarist government. Many of the cathedrals and larger churches have been converted into anti-religious museums or into workers' clubs. The beautiful Cathedral of the Redeemer in Moscow, a photograph of which I took, has, since our visit, been torn down to make room for a new Soviet palace of labor. People may still have church



CATHEDRAL OF THE REDEEMER

THIS HAS BEEN DEMOLISHED SINCE THE PHOTOGRAPH WAS TAKEN TO GIVE PLACE TO A SOVIET PALACE OF LABOR.

GROUP OF WOMEN PRISONERS

WOMEN'S PRISON IN MOSCOW

services, however, if 30 per cent. of the previous membership desire them. As a substitute for religion, enthusiasm for socialism and communism is systematically cultivated.

The imagination of the youth of Russia has undoubtedly been captured. They are enthusiastic about the five-year plan, proud of the present achievements of collectivism and are full of hope for a very bright future. A large part of the youth is thoroughly organized in three groups: The *Comsomols* (16 to 24), the *Young Pioneers* (8 to 16), and the *Octobrists* (4 to 8). Members of the Communist party instruct the Comsomols, the Comsomols instruct the Young Pioneers, and the latter instruct the little Octobrists. From these youth organizations, the Communist Party (with less than three million members now) will later be greatly augmented. The young

ST. ISAAC'S CATHEDRAL IN LENINGRAD

NOW CONVERTED INTO AN ANTI-RELIGIOUS MUSEUM. STATUE OF PETER THE GREAT ON THE LEFT.

people have many processions with flags and banners and they love to sing revolutionary songs. Most of these youngsters appear to be hilariously atheistic. Several of them asked me if it were really true that people in America still believe in God! The young people are also fiercely anti-capitalistic and are taught to believe that the world revolution is near. I was asked more than once when the revolution was coming in America; they seemed to think it was "just around the corner." They are taught to believe that all they can expect from the capitalistic countries is a

NIJNI-NOVGOROD IN THE DISTANCE

NEAR THE SITE OF THE NEW FORD AUTOMOBILE FACTORY.

revolver pointed at their breasts. Fear of attack by capitalistic nations is evidently promulgated with the idea of keeping up enthusiasm for the Soviet régime.

American engineers and skilled workers are highly prized in Soviet Russia. Men like Colonel Cooper and John Calder are looked upon as miracle-workers, for they have met and have overcome very great difficulties. In a recent play, entitled "Tempo," a Russian playwright, Nikolai Pogodin, has depicted the work of John Calder (under the name of "Mr. Carter") very vividly, and the audiences are said to greet with enthusiasm the acts in which this American engineer exhibits an inexorable will in achieving successes, despite the many obstacles that dismay the Russian workers.

MEDICINE IN SOVIET RUSSIA

Among the greatest of the changes produced in Russia by the Revolution has been the complete transformation of the medical situation. The desire to understand this, and to see for myself how it worked, was, especially after talking to Dr. W. H. Gantt, one of the principal motives of my trip.

I did not have the privilege of seeing Russian medicine under the old régime, but there is an interesting account of it in Colonel F. H. Garrison's recent ar-

ticle. Medical schools and hospitals in pre-revolutionary days were good, but there were too few of them. Excellent research work was carried on in important institutes of investigation and the names of Pavlov, Metchnikoff, Pirogoff and Filatow were world-famous.

But, in 1913, there were less than 13,000 physicians in the whole of Russia to care for a population of 150,000,000 people, and the majority of these were in the cities, so that the peasant population got but little medical attention. In some country districts there was only one physician to 30,000 or 40,000 people. Semi-trained men and women, known as *feldschers* and *feldscheritzas*, took care of emergencies, performed minor operations and had some skill in caring for the commoner diseases. Trained nurses were rare outside of the cities.

GROUP OF WORKERS
WATCHING A PHOTOGRAPH BEING TAKEN (LENINGRAD).

The death rate in Russian hospitals was high, especially in smaller places, and the infant mortality rate was the highest of any civilized country, being over twice as great as that of England and more than four times that of Norway. There was no central health organization and the private institutions and private practitioners did not work according to any common standard.

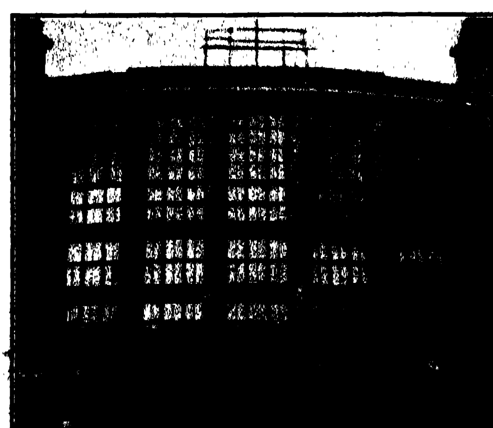
The Nationalization of Medicine: About the middle of 1918, medical institutions and the treatment of disease were nationalized in Soviet Russia and made a function and responsibility of the State. Semashko was appointed commissar of health and undertook this nationalization and socialization of medicine, asserting that medicine should be unified, that medical aid should be made accessible to all citizens, that medical treatment should be free for all, that the medical personnel should be suitably qualified, and that the main emphasis should be placed upon disease prevention. It was his plan to make all doctors, feldschers, nurses and pharmacists civil servants, and to see to it that all

hospitals, sanatoria and drug-stores should be State institutions. He realized the necessity of greatly increasing the number of available physicians and of medical institutions. Though he hoped ultimately to make all medical treatment free, he had to be satisfied with the compromise of providing free treatment for holders of health insurance, for soldiers and their families, for school children and for the poorest peasants. From the very first he laid stress upon the introduction of prophylactic measures for the reduction of the incidence of tuberculosis, venereal disease and epidemics, and he undertook, as rapidly as possible, wide-spread propaganda for the instruction of the people in the methods of maintaining positive health.

It was not until five years after the Revolution, however, that any well-organized form of State health insurance could be undertaken. Though the general principles and the coordination of this work depended upon central headquarters in Moscow, the actual provisions for health service had to be allotted to clinics and institutions of local health departments, the latter receiving subsidies from insurance funds. Against much opposition on the part of the medical profession, a Medical Workers' Union was organized to include doctors, nurses, druggists, laundresses and chauffeurs; prejudices against this union were gradually overcome and the meetings of the combined medical personnel led to a better understanding of the medical situation and to better cooperation among the different groups.

This commissar of health, Dr. N. A. Semashko, proved to be a man of extraordinary mental power and tact and soon justified Lenin's choice of him as the head of the State Department of Health. He gradually gained the respect and the loyal cooperation of a large proportion of the medical men in the carry-

STATUE OF ALEXANDER IN LENINGRAD



HOUSE OF REST

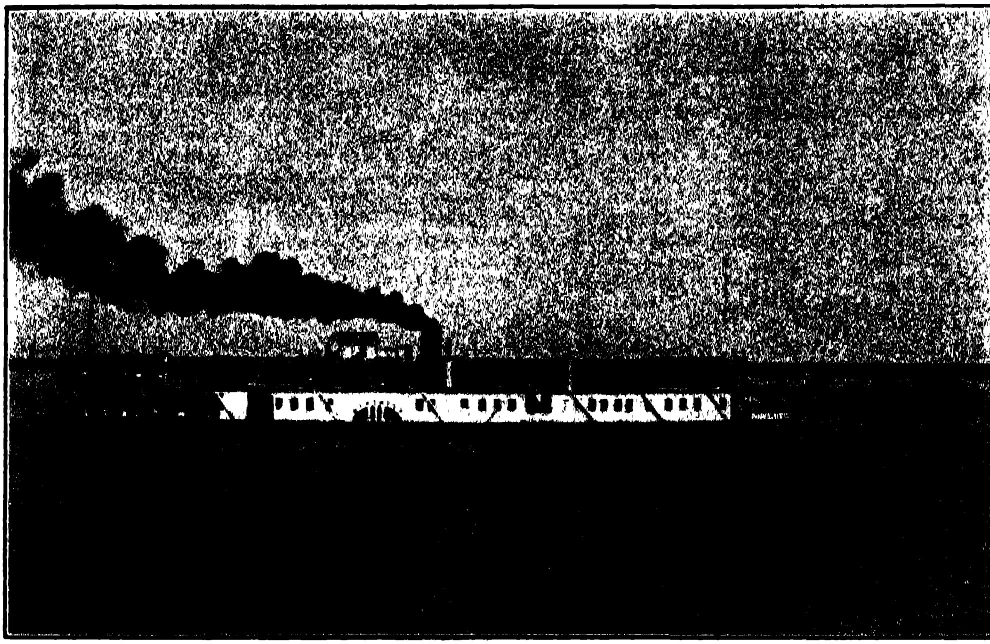
FOR WORKERS IN LENINGRAD.

ing out of his plans. As a member of the cabinet he was responsible for everything connected with the people's health and it was his duty to set up regulations promoting it. It was no small task to develop all the departments and bureaus that were necessary for curative medicine, for preventive medicine, for the teaching of medicine and for medical research. But, by virtue of his excellent ideas of organization and his ability to choose competent subordinates, he achieved a remarkable success and is generally looked upon as one of the most important of the real builders of the New Russia. He continued to be commissar of health for many years, but recently has given up, I was told, that post to undertake the supervision of the health stations of various sorts in the Crimea and on the Black Sea.

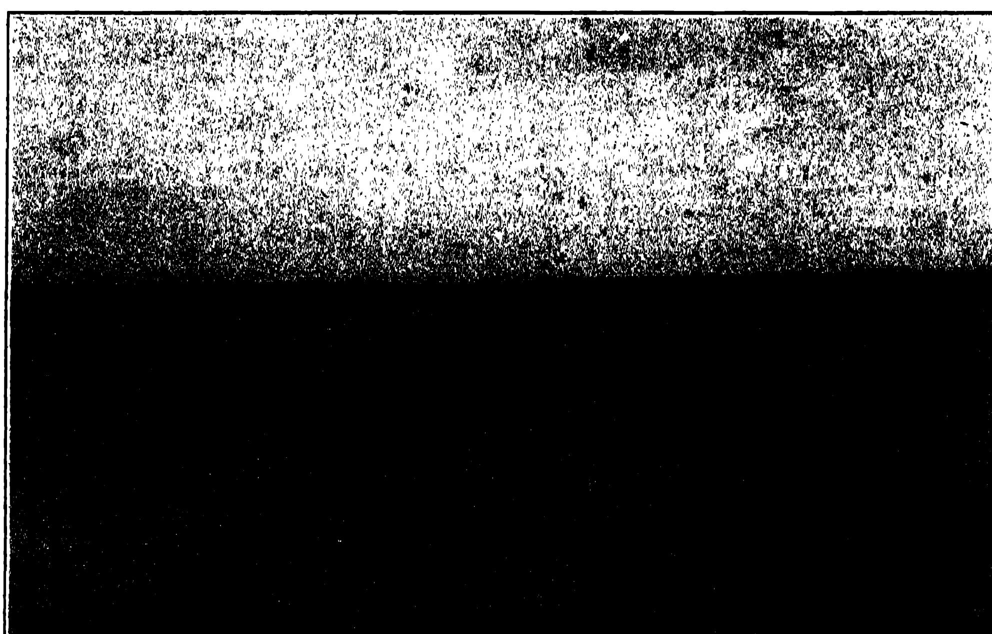
Medical Education in Russia: In order to supply rapidly a greatly increased number of practicing physicians, it was found necessary to make changes in medical education. By 1931, the number of physicians in Russia had been increased to 37,500, and it is expected by the end of 1933 to add 44,500 more so as to have then some 82,000 practitioners. Formerly, any student who desired to do so could engage in the study of medicine; now the students are especially selected; they are drawn chiefly from the families of the industrial workers and the peasants. This has necessitated special methods of preparation of the students for the study of medicine in the so-called "workers' faculties" and the teaching in these faculties, as well as in the medical schools themselves, has been made eminently practical at the expense of much theoretical instruction formerly given. New students enter the medical schools at two different dates each year. The course of instruction has been lengthened to ten months. The teaching is in relatively small groups, by the methods of the seminar or of the colloquium.

CROWD OF PEASANTS BOARDING A VOLGA STEAMER

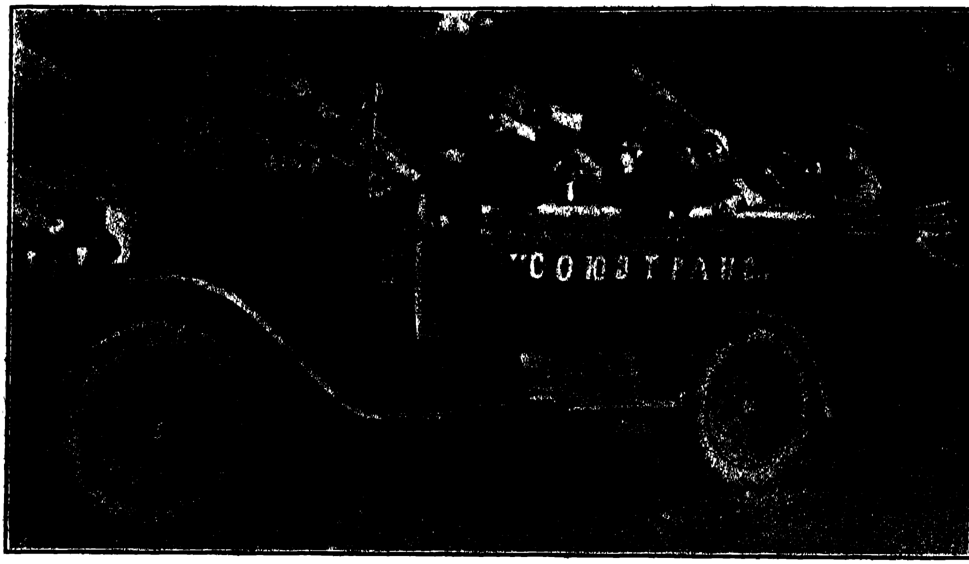
Each medical faculty is divided into three parts, (1) a curative-prophylactic



PASSENGER BOAT ON THE VOLGA

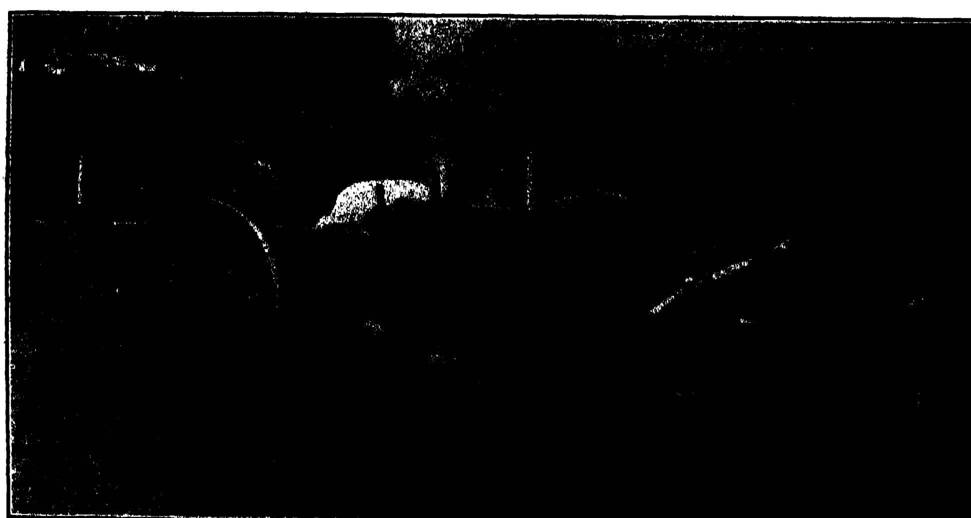


OIL BARGE ON THE VOLGA



INTOURIST BUS FOR THE GEORGIAN MILITARY PASS

faculty for the preparation of internists, surgeons and dentists; (2) a hygienic-prophylactic faculty for the preparation of public health officials, epidemiologists, food hygienists, etc.; and (3) a faculty for maternal and child welfare for training obstetricians and pediatricians. A medical student is, therefore, required to specialize almost from the beginning and he graduates as a specialist, rather than as an all-round doctor. There are more women medical students than men. In addition to the regular medical studies, students must have economic and military training, must study sociology and must take courses in dialectic materialism. The medical schools have been placed under the Department of Health

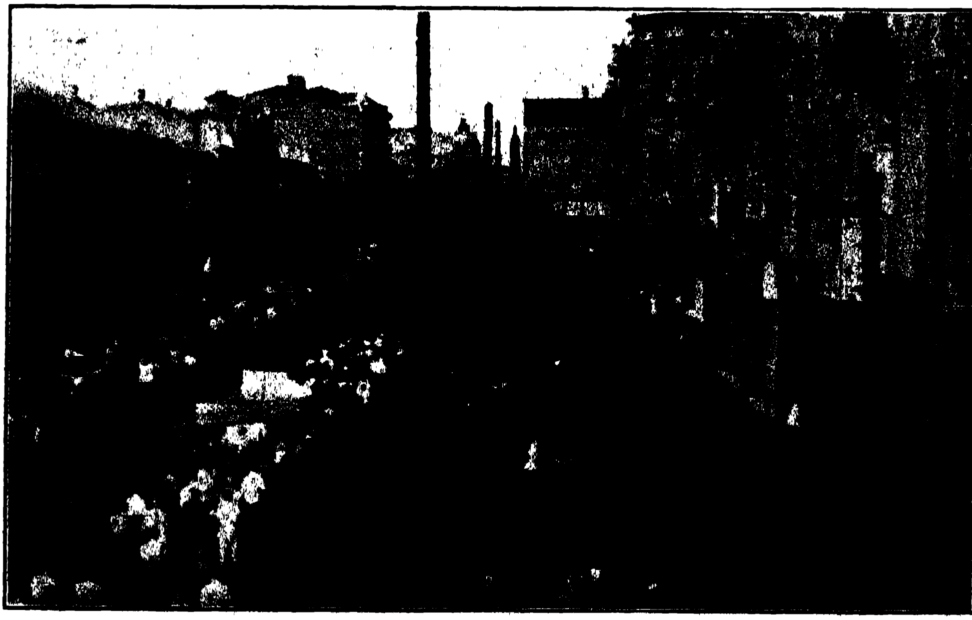


CHARACTERISTIC ROADSIDE SCENE IN GEORGIA

rather than under the Department of Education and thus are to be regarded now as technical schools rather than as university departments, though some of the medical schools are still under the aegis of the university.

The students, during their course, are taken into factories to study the sanitary conditions there, into the public schools to examine the conditions under which pupils work, and into the overcrowded homes of the masses to see where the hygienic defects lie. Thus, the medical schools lay great stress upon the social service point of view and upon a knowledge of the methods of preventing disease as well as upon that for treatment of disease. Similar efforts have been made to increase the number of women who study nursing and to improve their training.

The Practice of Medicine and Hygiene in Soviet Russia: While we were in Moscow we had the privilege of interviews with Professor Petrov, who is at the head of the Society for Cultural Relations with Foreign Countries, and with Dr. Oettinger, who represented the Central Department of Health. In addition, I had several talks with Professor Roman Luria, of Moscow, interviewed the head of the Woman's Clinic and the head of the Dietetic Institute in Leningrad, and talked with Professor Buchstab, the head of the Heart Clinic in Odessa, as well as with several of the research workers in various institutes of investigation. I also had a long interview with Professor Kairpinsky, the famous polar geographer, who, though over eighty years of age, is still the president of the Academy of Sciences in Leningrad.



PARADE ON DEFENSE DAY IN ROSTOV

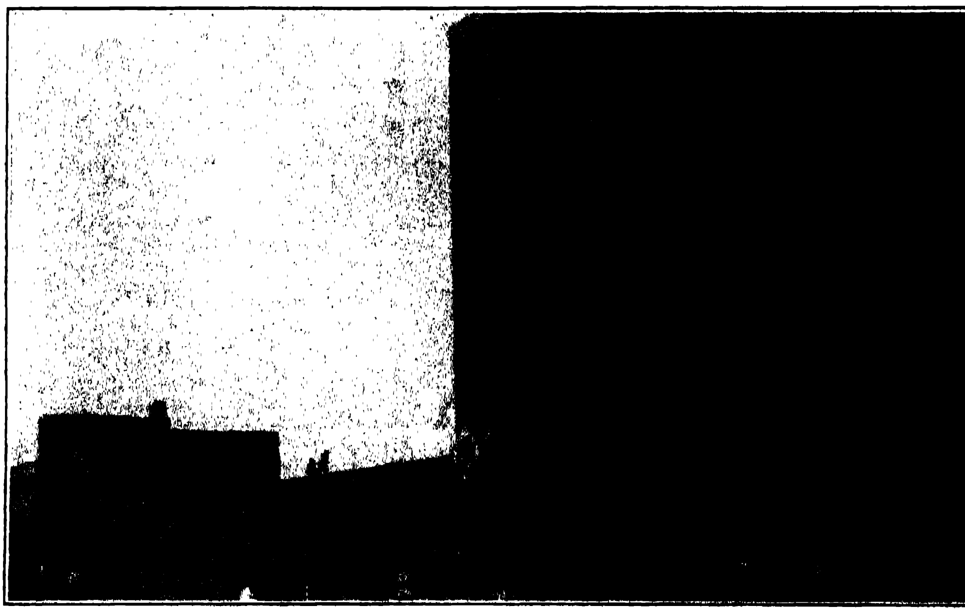
In Russia, disease is no longer a private and personal matter. Since every inhabitant is a social and economic unit, disease is looked upon as harmful to the State, and restoration of the sick to health, the prevention of disease and the cultivation of positive health are regarded as State responsibilities. In

other words, Soviet Russia is witnessing, for the first time, the efforts of a thorough-going State medicine.

Not that private practice has been entirely abolished in Soviet Russia, for though every physician is required to work six hours daily for the State, he may, after that work has been done, treat private patients and be paid for such treatment if any desire him. It has not yet been possible fully to realize the ideal of making competent medical care accessible and free to all in the institutions organized by the State, and it is because of the delay due to insufficient personnel that the doctors still have some private practice. It is believed, however, that private practice is doomed ultimately to be wiped out as the numbers of physicians increase and as State institutions are multiplied.

The Central Department of Health, at the beginning, gave most attention to the control of epidemics, to maternal and infant welfare, to campaigns against tuberculosis and the venereal diseases, to the treatment of drug addiction, to the lessening of the abuse of alcohol and to the organization of State dispensatories and prophylactoria.

On account of the doctors graduating as specialists, it became necessary to organize them into groups in "unitary dispensaries," each such dispensary serving a district of say 30,000 people with approximately 1,000 daily visits from patients. At a dispensary, every person of the district must report for examination, whether he be sick or well, and he is studied, though I fear rather superficially as yet, by a group method of diagnosis, the results of the study being placed in the worker's "Sanitary Diary," a booklet that each visitor must present on his periodic returns to the dispensary. The social factors of disease and the collective measures for the prevention of disease receive the great-



ADVICE FROM LENIN

FORM OF PROPAGANDA ON THE END OF A FACTORY BUILDING IN STALINGRAD, "WITHOUT THE BOOK NO KNOWLEDGE; WITHOUT KNOWLEDGE NO COMMUNISM—LENIN."

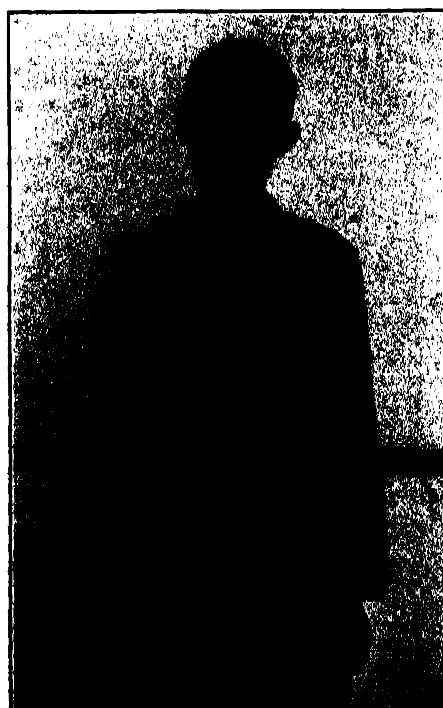
CAMEL, THE SYMBOL OF LAZINESS

PLACED BEFORE THE FACTORY UNIT THAT FAILED TO COMPLETE ITS QUOTA OF WORK.

est stress. The conditions of the different occupations are carefully studied and the living conditions of the people in their homes are investigated with the object of instituting suitable preventive methods.

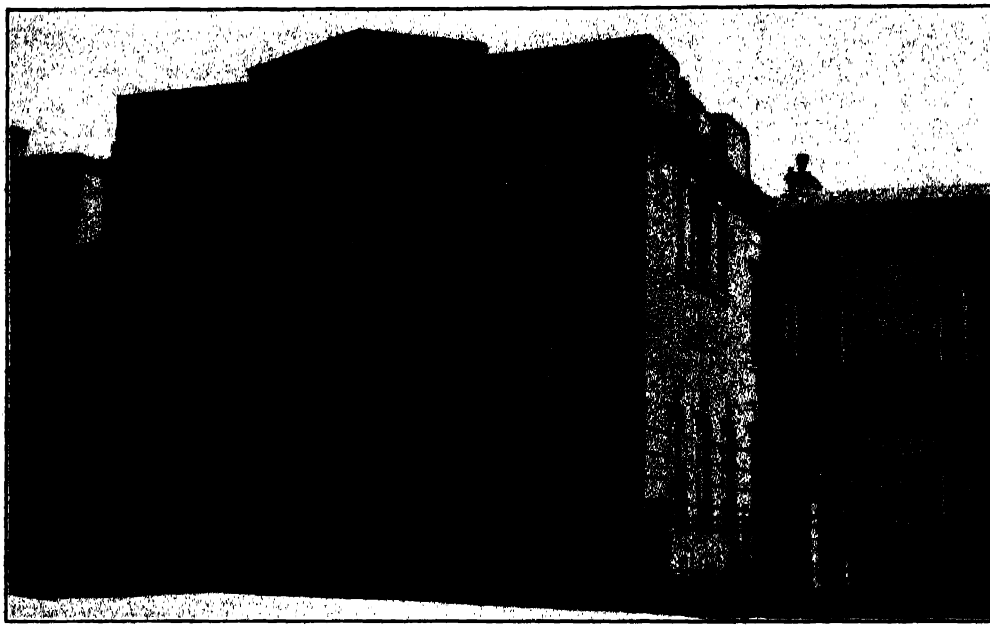
A great variety of forms of propaganda are made use of for the education of the masses in health measures. There are many public lectures, many articles in the newspapers, many radio talks, many moving pictures, a large series of colored artistic medical posters, many health museums and traveling exhibits—all of which are directed toward the instruction of the people in the causes of disease, in the ways of avoiding these causes, and in the modes of life best suited for the maintenance of positive health.

The authorities in Soviet Russia have introduced certain institutions that might well be imitated in other countries. Thus, undernourished children are sent to the so-called "forest schools," where they live for two or three months or longer under ideal health conditions, gain weight and are taught how to eat and how to live before being returned to the ordinary schools. Persons predisposed to tuberculosis or suffering from incipient tuberculosis and yet capable of some work are cared for in "day sanatoria" or "night sanatoria," close to the places in which they work, until they are believed to be in condition to live ordinary lives outside. In connection with the larger factories where one or more meals may be supplied during working hours, factory diet kitchens prepare four or five different kinds of meals for workers who have been found to have gastric hyperacidity, gastric anacidity, constipation, obesity or undernutrition. In one of the dietetic insti-



AN UZBEK

A FELLOW TRAVELER ON THE BLACK SEA BOAT.



ONE OF THE MEDICAL CLINICS IN MOSCOW

PART OF THE HEART CLINIC OF PROFESSOR BUCHSTAB IN ODESSA

tutes devoted to the study of food needs of the workers, I was given two meals, one for hyperacidity and one for anacidity, and ate both of them!

Venereal diseases were formerly very prevalent in Russia and are still widespread, though the Department of Health is making a vigorous campaign against them. An attempt is being made to reduce the number of prostitutes, and through the Workers' Clubs and the Sailors' Clubs many healthful opportunities for companionship, for games and for interesting studies are offered so as to reduce the temptation for seeking the companionship of prostitutes.

legally in a gynecological clinic, provided a committee of three members, including a physician and a social worker, approves. At the Woman's Clinic in Leningrad I saw two such abortions performed by two of the women assistants of Professor Podsoroff. One of these abortions was done under an anesthetic, the other without it. When I asked why these abortions had been legalized, I was told that the women otherwise would have them done by unskilled quacks and that the mortality among women thus treated had been very great; since the legalization of the abortions, the women apply to the gynecological clinics where

PROFESSOR ROMAN LURIA

OF THE MEDICAL CLINIC (FIRST FROM THE LEFT) AND THE STAFF OF THE RESEARCH INSTITUTE OF BIOLOGY AND MEDICINE, MOSCOW.

The ease of marriage and of divorce and the free circulation of information regarding birth control are also said to be effective antidotes to prostitution.

Every child born in Russia, whether in or out of wedlock, is legitimized as the handicap of "illegitimacy" is considered to be unfair to any child. Moreover, up to two and a half months of pregnancy, a woman who does not desire the child may have an abortion done

the operations are performed skilfully, aseptically, and with almost no mortality. At the woman's clinic I visited, I was told that from ten to fifteen such abortions for "social reasons" are done every morning.

Much attention is paid in Russia to physical methods of therapy. This was very obvious at the Heart Clinic in Odessa, where Professor Buchstab, in addition to ordinary wards, has a large

FORMER PRIVATE VILLA

BEING CONVERTED INTO A SANITARIUM. SERVED AS LODGING FOR OUR PARTY IN SOCHI.

institute of hydrotherapy, provision for mechano-therapy of all kinds, and a large park connected with the clinic for open air and rest treatment and for graduated exercises.

The mineral water resources of Russia are being developed and spa treatment is becoming ever more popular. We visited the sulphur springs at Motesta (near Sochi) where many seemed to have great faith in the efficacy of both the external and internal use of the sulphuretted water.

All along the Black Sea and in the Crimea, the confiscated palaces and villas of the rich have been converted into vacation places and convalescent homes for the workers.

Research Institutes and Medical Publications in Soviet Russia: The number of institutes of research has been markedly increased in the larger centers since the advent of the Soviet régime. It has been possible, too, to retain as the heads of some of these institutes important scientists of the old régime, many of whom have not been sympathetic with the Revolution. There is a tendency, however, to place at the heads of the newer institutions, as rapidly as possible, young scientific workers who are socially and politically in tune with the present authorities. In every scientific institute, in addition to the scientific director, there is a Red director who controls the budgets and approves the appointments made.

The workers in the scientific institutes are informed that the old slogan of "science for science' sake" must be replaced by the slogan "science for practical application." Moreover, the doctrine that science should be combined with political economy and with world history into a unitary view-point, namely, that of dialectic materialism, is promulgated.

Though religion is still to a certain extent tolerated in Russia, religious organizations are not permitted to do social service work, charity medical work, or anything of the sort. Many of the

churches have been turned into anti-religious museums or into workers' clubs. Even foreign scientists invited to give medical lectures in Russia are criticized if they give expression to doctrines that are in conflict with dialectic materialism. Thus, the distinguished German pathologist, Aschoff, who was invited to lecture on pathology, was, I was told, much criticized because of his vitalistic views in pathology; as one man put it, "We do not want God smuggled into Russia in the form of vitalism." One native professor who had made important discoveries in histology and physiology but who had religious tendencies was transferred, I heard, from the post he held to another "in which he could do no harm." Still, on the whole, I was impressed with the fact that the Soviet authorities desire to foster and encourage medical research, and I could not help but have real admiration for the scientific workers in Russia who are endeavoring to hold the torch aloft despite the difficulties encountered.

It is reported that there are about 120 medical journals in Russia, this number including those published in languages other than Russian in the several autonomous Soviet Republics. The results of the more important scientific researches are, however, apparently published still abroad; formerly they went to French journals, but now, owing to the political situation, the German archives are more popular.

On our return from Soviet Russia, we were very glad that we had made the trip, and can recommend it to all who are interested in observing for themselves the conditions under which a novel social and economic experiment is being undertaken.

We are of the opinion that it would be wise for the United States to give diplomatic recognition to Soviet Russia, since this does not mean approval of its social or economic system but would favor the revival of trade relations and these in turn would tend to minimize the dangers of friction between the two countries.

SMOLNY INSTITUTE IN LENINGRAD

WHERE LENIN AND HIS WIFE LIVED DURING THE REVOLUTION.

SEBASTOPOL ON THE BLACK SEA (CRIMEA)

TYPICAL WHARF SCENE ON THE BLACK SEA

Following is a list of selected references which will be of interest in connection with the foregoing article:

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"Soviets in World Affairs." By L. Fischer. New York, 1930, 2 vols.

"Mind and Face of Bolshevism." By R. Fülöp-Miller. New York, 1928. 448 pp.

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"New Russia's Primer; the Story of the Five-year Plan." By I. I. Marshak. English Translation. Boston, 1931. 162 pp.

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RESEARCH AND INDUSTRY

By Dr. WILLIS R. WHITNEY
DIRECTOR, RESEARCH LABORATORY, GENERAL ELECTRIC COMPANY

In science, the mathematicians are now in the saddle. It is no longer necessary that a thing should exist in a form suitable for our imagination. If we know mathematical equations, we may proceed systematically to the utility, trusting that the understanding will advance with later familiarity. Most of our basic facts are quite beyond pictorial analogy. For example, the fundamental mechanics of light, of heredity, of thinking, of destruction and of creation are being left for the millennium. Meanwhile, the pure mathematician is directing our groping steps and suggesting many experiments. I name some number. Someone adds to it. Someone else multiplies it by something, and someone may subtract something from it. Let us say the result is number 49. So far that is nothing but a number. But multiplied by the right idea, it becomes perhaps a market price, your age, the year of the California gold rush, the area of some strip of land, or the size of a suit of clothes. You know at once that its names may be infinite. You were taught not to add numbers of different things, like horses and wagons, but you may do so, and you may multiply numbers by anything if you are so minded.

Let us, then, observe the wonderful complexities which are multiplying in the electro-magnetic field, where infinite possibilities in the radiations, or rays, promise countless new technical and social changes. I shall illustrate what I mean by the use of simple units, though I do need about all the numbers.

No one cares particularly what unit was used in labeling his radio dial, providing the numbers are useful. So I select corresponding and reasonably correct numbers without full explanation of the unit—call it a ten thousandth of one Ångstrom, or four tenths of a trillionth of an inch. But while the numbers on your dial may extend from 500 to 1,500, my new numbers, covering all conceivable rays, extend from unity to infinity. Moreover, the same peculiar unexpectedness of service and message appears throughout the whole series, just as is found in the narrow range of the parlor radio set. In other words, within a little group of numbers on a radio dial we find utility or advertising, music or pictures, and messages of all sorts. Moreover, if we stick to a single number we may get all sorts of information in time, and all the other numbers may treat us similarly. Even in the narrow range of radio, the possibilities are enormous, and it is a very young product. But contemplate for a moment what may be the possibilities between number one and infinity.

For analogy, consider bells. All their messages radiate through air (but not empty space) at 1,100 feet a second, regardless of the size of the bell. The utility or message of the tiniest bell on some kitten's neck is distinct from that of the fire alarm or church bells, but from the smallest to the largest of bells, the range is really very small. Representative numbers based on weight of the bells, frequency of the vibrations or wave-length of the air waves, would hardly extend from unity to a million. But the numbers applicable to electromagnetic possibilities, on the other hand, extend from one, clear through the quintillions of ordinary alternating current, on to infinity. Thus I have numbered from one to infinity all the

different forms of available energy which radiate at the velocity of 186,000 miles per second—what I call practically infinitely fast, for nothing will ever go faster. My numbers are not quite individualistic, but are like population statistics. For example, the inhabitants of one farm may be roughly between one and ten, of villages from 10 to 1,000, cities from 10,000 to ten million, etc. But behind both systems lies a certain possible effect of each individual. Number 3 on the farm may be a potential president, number 999 in a village may do his service in jail.

So what I am numbering from one to infinity are the different electrical possibilities. I have chosen the numbers to correspond to what I will call a kind of length, just as the men in a city might be consecutively numbered as to height, weight or skill. There may be no wave-lengths to rays, but we can still use the numbers, and the main point is that the scale is infinite and each unit has many possibilities.

It was only a few years ago that this completeness of our electro-magnetic numbers was first recognized, and now the greatest sport in physical science or in electricity is experiencing the surprises of new numbers. New groups of numbers, like safe-combinations, turn out to be combinations for unlocking unexpected utilities. One may say that every novel combination so far has opened some surprise which only subsequent research has deciphered. For example, after we first saw our bones through our bodies it took years of work to learn the numbers we had used. The safe, so to speak, was opened by accident, and no one at the time even suspected that the combination consisted of electro-magnetic numbers rather than dynamite.

Cosmic rays at present fit the lowest numbers, which I start at unity. The numbers of these radiations, which Dr. Millikan is studying, range from 1 to 10, and suggest some ultra-microscopic electro-magnetic sender, and consequently complete wireless station of inconceivably short wave-length, like some bell which is far too small to be seen by any microscope. The messages in this numerical range seem to be telling us about the formation of matter, the birth of stuff, the click of energy.

There is a discussion going on among astronomers and physicists as to whether the universe is really running down, or just running around. Men had thought it was running down. Everything that we can do to keep the Humpty Dumpty universe on the wall really seems to lower the wall a little. We apparently can not do anything and still leave the outfit quite as well off in energy as it was before. Moreover, we know now that some of our elements are just naturally falling apart and decaying in a way that has seemed to have no reconstructive counterpart, and there appears no way of even delaying the decay. But out of cosmic space somewhere there are coming rays of numbers one to ten, and if our ideas of these little numbers are correct, they may be a kind of space-reverberation of riveting of the constructional mechanics by which our smallest atoms are being built from nothing. This nothing has emphasis on the final syllable, for they seem built of energy and not things. And so our first electro-magnetic numbers represent rays that will penetrate many feet of the densest substances and still record themselves on little electrical counters just like the devices used for handling the much larger numbers.

Next to the cosmic numbers 1–10 come those of 10 to 1,000. This group represents the gamma-rays of radium and similar messages from the inside of heavy atoms. They tell us of the gradual destruction of matter under local conditions, and the history of our ele-

ments. That is, we have thereby learned the intermediate ancestors of matter. These rays have the power of making air conducting for electricity, just as do the cosmic rays and adjacent higher so-called x-rays. Here again each individual number will some day prove to carry a special message, and, as in other cases, it will probably be found that many different services can be performed by each one, just as each apparently tells us now of some greater or lesser earthquake in atoms.

The common x-rays are numbered from 10,000 to 100,000. Nothing would have seemed more unlikely a few years ago than that this invisible light would usefully shine through our bodies as well as through bodies of wood and iron. It took several years to discover that these rays were also in the electromagnetic series. Still newer messages are now being received from them constantly. Without referring to therapeutic uses of both radium and x-rays, we should note that pollen, seed and plant, sperm, egg-cell and animal are all affected by this group of numbers. Recent biological work seems to promise new types or forms of plant and animal through action of these rays upon the mechanics of plant and animal heredity. They seem to affect all living things just at the time when these have not completely determined just what they want to become.

Just as unbelievable service is coming from the numbers 1 million to 35 million. This has been called the ultraviolet range. They are invisible in the ordinary sense, but living nature seems to be particularly sensitive to this group. Here, too, the messages are quite unforeseen, and are daily being augmented. In young animals, certain blood deficiencies account for lack of bone-growth. This has been shown to be due to food defects, lack of light, or both. One of the components of food which is necessary for normal growth has been named vitamin D, and it has been shown that this is producible by our numbers one million to thirty million from materials which contain certain organic compounds part way up the scale towards this vitamin. Here, as elsewhere, it is clear that numbers very nearly equal to one another do not serve this purpose equally well, and are in some cases even antagonistic—again a proof that these individuals are highly individualistic. Recent work on the radiation of food by a moderate ultraviolet range has shown the need of selecting within that range certain numbers and omitting and actually cutting out others. Perhaps as remarkable as anything in this group of rays is that they may be applied directly to the diseased animal and cause the same bone growth and recovery of normal blood composition as though the product of the action of the rays on its foods were eaten. It is interesting that numbers in the thousands of the x-ray group are used to photograph and thus demonstrate the changes as they are being brought about in rhachitic animals by exposure to the numbers in the millions. Both services are fairly modern technical advances. Both were rather unpredictable and quite specifically individualistic and valuable.

This series of electro-magnetic food messages fits wonderfully well into other knowledge of foods, where already five or six essential vitamins are recognized. On the other hand, this work also fits the reactions of simple chemistry without reference to life reactions. For example, the production of ozone from oxygen is brought about by numbers near 20 millions, and the reverse production of oxygen from ozone by numbers about 60 millions. Many organic chemical reactions are brought about by numbers between 20 million and 24 million.

Such discoveries, now firmly established, are suggesting countless other experiments, and thus probably all growing matter and many inorganic processes will be investigated as to the effects of rays of particular numbers.

Our electro-magnetic numbers include ordinary "light" as well as "long wave radio," so that we might expect to find some new choice of words for explaining ordinary light. How is it a wave and how a group of darts? Does it arrive without coming, or should it be accepted as an event without fixed explanation? On my number scale, visible light extends from 35 millions to 76 millions. It is hopeless to outline the countless utilities and messages of this particular range, but I ought to point out that even here there are also infinite shades and colors, and each number tells us something new. The actual composition of the celestial universe has been broadcast to us in thousands of these spectral numbers, and many have only recently been translated into words. (The number 58,760,000, called the helium line, told of helium in the sun long before the stuff that fills Zeppelins was discovered on earth.) They tell us of the breaking down of all our chemical elements in sun and stars under conditions of temperature and pressure which are quite beyond our comprehension.

Beyond the light rays are the heat rays, 80 million to ten billion. The penetrating power of some of these through living tissues has been studied because it may be desirable and possible locally to raise internal body temperature higher than by the older methods of direct thermal contact.

From one hundred billion to a hundred trillion there is a great range called the Hertzian. These waves are too long to be felt as we feel heat, and too short to be used in radio. No one can tell what uses may be found for them, but watch out!

Then come the longer waves which approach those of short wave radio. These are numbers from a hundred trillion to a thousand trillion, and one selected part has interested me because of its fever production, as I will describe it later.

The short wave radio corresponds to numbers around ten thousand trillion, and these are being used more and more for around-the-world broadcasting, because, being shorter than those used earlier, they are reflected from the conducting layers at the top of our atmosphere better than the longer wavelengths which tended more to go directly out into interstellar space.

The ordinary broadcasting range involves the numbers from 20 to 60 thousand trillion. I can not see why there may not be sufficient units in this range to allow for new applications to needs quite unthought of as yet.

If we continue our numbers upward, we finally reach the old familiar alternating currents, for their waves at say 500 cycles and 60 cycles are similar to our most familiar light except that the numbers are respectively sixty and five hundred million trillion. All these electro-magnetic waves, from one upward, seem to travel at what I have called equal and infinite velocity. I just say that. Ordinarily we attach the number 186,000 miles per second to this rate. But the mathematicians show us that it is faster than anything (however small) could be made to move (no matter how hard it was pushed), so it seems practically infinite and fits better my crude idea of what electro-magnetic speed ought to be. Moreover, the thing pushed, in our case, if it really goes through space at all (as distinct from sitting on the borders) is simply called energy.

It may be of interest to tell briefly about a few tests we have made, using radio energy in fields apparently quite

remote from technical affairs. They owe their origin almost entirely to the fact that new kinds of radio tubes were being developed faster than I could understand them, and so I decided to play, in spare time, with a few so-called tube circuits, for my personal orientation. It is also more fun telling about my own personal researches than of the work of other men of the laboratory. They should tell their own stories.

"Research and Industry" is the title of this article, but the thought behind most of it is that some research may be quite vagarious and capricious. When carried out in large industries many byways are fortuitously opened and byproducts investigated which evidently could not be intelligently planned before or at their beginning. In general they do not warrant vigorous attack until some comprehensive or promising stage has been more or less accidentally attained. The start of this particular research on radio was quite unrelated to industry.

The first experiment was an attempt to grow, by radio catalysis, a gall on a plant on my farm. I was just letting my mind wander, perhaps, but I had long been interested in the similarities between plants and animals. Both grow from fertilized cells, both are connected colonies of countless individual cells, both have circulation systems, and even the chlorophyl of plants reminds one of the protoplasm of animal life. They developed from the same original aqueous life, and both retain circulating salt solutions called sap, plasma or blood. I had read about the similarity between animal and plant repairs, scar tissues and tumors. I was surprised to see how many different plant tumors and galls there are. Many of them are due primarily to the deposit of an insect's egg into the living part of the plant. The plant produces a maternity hospital for the insect. There was a variety of explanation of this abnormal plant growth. It has been attributed to formic acid or other chemical agent supposedly introduced by the insect which planted the egg. Then it was credited to certain bacteria which infected the plant when the egg was laid. If it is an evolution to provide a home for a growing insect it seems worth while to attribute it to some factor which is a necessary part of the growing insect itself. I still do not know the cause. A simple case is the goldenrod gall. There are several types of these, but one is a spherical growth nearly an inch in diameter which quite commonly occurs about three quarters the distance up the stem of the American goldenrod. I had played with this for years, and had noticed that there was another goldenrod gall, not spherical, but cylindrical, several times as long as it was wide. The grub or larva which occupies such a gall is nearly spherical in the spherical gall, and is a long worm in the cylindrical gall. So it seemed possible that the galls were just places where the rate of plant-growth was raised above normal by the slightly elevated temperature of the egg and larva. It is no stretch of imagination to think of insects as warm, and even in living eggs energy is consumed, so heat is generated. Such tumors, or galls, are like animal tumors; they are proliferations, or excessive growth of normal tissue, and the cells are characteristic of that part of the plant or animal in which they grow. This is well known.

Every chemist knows that, in general, rates of chemical processes rise between two and three-fold for each ten degrees Centigrade rise of temperature, and this might mean a possible very appreciable gain in mass for that part of the growing plant which was heated above its environment. So I thought that if I could put the hot greenhouse inside the plant instead of the reverse, I might grow a tumor there.

In the very high-frequency radio-field we had a device for heating certain types of resistance at remote distances. A whole plant could be warmed internally by submitting it to the electromagnetic field, but the degree of heating varies also with the nature of the thing to be heated. I realized that an insect's egg or larva could not be easily imitated, but I found that a very minute piece of steel, the tip of a very fine needle, could be inductively warmed enough to slowly melt its way through wax even when the power was low and the coils or antenna were at some distance. So I concluded that this heat or power could not injure the plant. The tiny needle-points (my warm eggs) I inserted into the stems of young, potted goldenrods, and applied the radio energy for a summer, and then repeated it the next summer. But except for a gall which grew on one of the plants from an egg which, without my knowledge, was already in the stem, I never succeeded in producing a plant tumor. I have not given it up, but I have learned a lot about plants without learning how they do determine new growth. Probably they, like the trees, grow only in a sort of shell surrounding their past growth, the cambium about the idle wood. The little gall fly knows better where to put her eggs than I do. My steel eggs either remained dormant just where I put them (while the stem placidly extended above them) or, when I had put the needle-point right into the growing tip, it was later found at the top of some young leaf. I could not grow a tumor. And I could not give up. It seemed certain that extra heat inside a plant should speed up local growth, just as putting a whole plant in a warm place forces all the parts. So, though it may be foolish to admit it, I tried again, with the same idea applied to growing onions and to small trees, but without getting the particular narrow-minded result I sought. We did learn, incidentally, as often happens, that it was easy to kill the grub in the galls by application of the radio energy, and we knew that this was due to the grubs being overheated internally. This led to experiments on fruit-flies, because they are the test-tubes of the biologist. We found that when ice cold air was blown through a tube of these flies they immediately hibernated and seemed dead. If, now, we applied the radio field while the air and all the surroundings were still at ice temperature, the flies became lively and flew about, and with a little more external radio energy they would die from internal overheating. This was destructive, but not productive.

Such experiments led to others on rats and dogs, for here we could measure the induced temperatures and follow the effects. At about this time, some of the engineers thought they felt the energy in their bodies, their knees heated when near a large generator, and this was investigated. It was found that a man near a large outfit of unusually short wave-length rose in blood temperature a degree or more.

In our experiments we had first made imitation animals out of gelatine. Instead of sweetening our jellies, we used common salts and studied those concentrations corresponding to animal blood. In this way we found that the heating effect varied with the salt concentration, and that with any particular concentration like normal blood, we got the quickest heating when a certain wavelength (number approximately ten thousand trillion) was used. Later we learned that, given such data as conductivity and dimensions, it is possible to calculate what electrical hook-up will best serve a given purpose.

It was not at all clear, even when we knew that the heating took place within the body fluids, that it was harmless,

and for that reason our jelly rats were followed by real rats. The early work with little numbers like ten thousand (or x-rays) had shown one of the most remarkable known biological effects, and we had repeated it on insects. Rays in the range ten to one hundred thousand do something destructive to living matter which may not disclose itself for years, but, by increasing the dose, the effects may be brought out quickly. So with x-rays, we had treated fruit-flies in lots of a hundred to different doses while they were in closed wooden boxes, and we found that while homeopathic doses did no harm, larger doses insured a regular subsequent time for death, an exact death-expectancy. For example, after a certain dose, the flies would live for ten days, but die in twelve. Two half doses were equal to one full dose, etc. We found no such effect with number ten thousand trillion, however. We found, instead, that rats liked a certain amount of this radio heat. So we made a long glass house, in one end of which the radio field could warm the rat without heating the house, and in another part there was an ice-cooled box. Thus the rats could choose their preferred temperature. They soon moved their cotton bed into the electro-magnetic field. Then we gradually, from day to day, increased the intensity of the field, so they became warmer and warmer. No one knows how far we might have gone, but one day one of the rats came hurriedly out of his warm bed leaving his tail in the cotton. The tail proved to be entirely dried out. The rat was unhurt except in appearance, and ate out of my hand at once. Now I am not advocating this as a painless surgical process, but will the day ever come when we may be warmed internally in unheated houses by some external radio field? It might be useless to heat our houses with all their contents including the air, if we could get along by internally heating ourselves. Our early ancestors did it without radio. They carried enough heat with them, and their rooms were not heated in their absence. If we carry the body temperature higher than about 98° F. we say we have a fever. We found first with rats that fevers were harmless unless above 106, and rats have withstood 111°. Dogs can not usually recover after being exhausted by several hours of electrical fever of, say, 107°, but all animals stand indefinitely a few degrees of fever. It is a wonderful way of reducing weight, for the animal peacefully perspires his fat away. This is not advertising for reducing.

One day a veterinary brought us a little white Boston bull terrier which he said was going to die of dermidectic mange. It couldn't do any harm for us to experiment on her, and we accepted her as a gift and called her Lydia. Enclosed in her little wooden kennel, she was subjected to an hour's electric fever daily. It is a long story full of human interest, but the dog got well. The human interest was so great that Lydia also got all the medicine we could think of, in addition to the fevers. She was put on a strict diet daytimes, and accompanied the watchman on his rounds at night, so it may have been a faith cure. It was clear, however, that repeated electrical fevers do not hurt small white bull dogs.

All this in turn led to our finding that human fevers may not be all bad, but some are probably beneficial, and we learned about the work of Dr. Wagner-Jauregg, of Vienna, who had cured cases of advancing paresis by producing at will fevers of malaria in the patient. There was only one thing to do then. We made a few devices and lent them to institutions where it seemed probable that the indicated studies could be well made.

It is not new to heat the body by external means and to produce fevers thereby. It has been done by hot water baths, but the patients usually have to be tied down before they will submit to it. It is also not new to heat a human being by strapping electrodes to him and applying alternating current of high frequency, but it is new to heat the individual by radiations or electromagnetic energy emanating from an antenna. For uniformity, the present method is to let the patient lie on a cot with antennae plates above and below, but not touching him. It is at present being studied largely as a substitute for the purposeful malarial fever infection which is the wonderful service Wagner-Jauregg rendered after painstaking studies over many years. I do not profess to know the action, but the guiding thought was this: In such diseases as paresis there is a blood parasite whose ultimate goal seems to be the brain cells of the host. It gets there effectively only after a long siege in the blood stream and spinal fluid, but the mind is finally affected, and until Wagner-Jauregg's work, I believe that there was no cure. He showed a way, through introducing fevers, to save at least some of the afflicted. It seemed a natural thing to assume that the fevers finally made the parasite give up in disgust, not being able to stand the heat. This general principle must be tried on various human and animal troubles. There are now several groups of competent American doctors and research men in well equipped institutions who are making these studies, and it seems from their reports that there is hope for service from this particular radiation number, ten thousand trillion.

COSMIC DISTURBANCES OF THE EARTH'S MAGNETIC FIELD AND THEIR INFLUENCE UPON RADIO COMMUNICATION[1]

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Purpose and Scope

It is hoped to show this evening that there are correlations, found by observation, to exist between (*a*) the strength of long-distance received radio signals, (*b*) changes in the apparent height of the ionized layers of the upper atmosphere, (*c*) changes in the Earth's magnetic field, and (*d*) disturbances on the surface of the Sun, as revealed by sunspots. Certain of these different phenomena are interconnected in recognized ways; but the reasons for the observed correlations between others are still mysterious. In order to solve these difficult cosmic problems, more numerous and more varied observations are needed, as to what is taking place in the upper atmosphere, and beyond. It appears, however, that by carefully studying the behavior of radio waves, directed experimentally skywards and received on the ground, after being reflected back from different elevations, it may be possible to throw light upon the nature and constitution of the otherwise inaccessible upper air.

The Ionized Layer or Layers in the Upper Atmosphere

In the early days of radio telegraphy, before the beginning of the twentieth century, it was supposed that when a simple radio impulse was started from a mast at a sending-station, a hemispherical electromagnetic wave was emitted from the mast as a center, like the upper half of a soap-bubble, expanding in all directions at the speed of light. The lower edge of this invisible hemisphere ran over the conducting surface of the ground or sea, in all directions, north, south, east and west, at the rate of 300,000 kilometers per second; while the top of the hemisphere shot upwards also at this speed. Only the lower edges of this wave, near the ground, could carry the impulse to receiving-stations. The electric energy in the upper portions of the hemisphere would be useless for communication. This was the then generally accepted doctrine of three-dimensional expansion of radio waves.

When the Marchese Marconi came to North America in the late fall of 1901, to see if radio signals could be received from England across the North Atlantic Ocean, he was able to report receiving groups of dot-impulses caught in Newfoundland by a kite-lifted conductor, as emitted from his sending-station in Cornwall. The amount of energy required to operate the receiver was greater than should have been obtainable from the emission in England upon the three-dimensional hypothesis, and it was necessary to invoke some suggestion for preventing the heavy loss of energy upwards during transmission. It had been shown by Sir J. J. Thomson that highly rarefied air was capable of conducting electricity better than sea water, so that it was reasonable to assume that at an elevation of nearly 100 kilometers, the air was sufficiently rarefied to act as a conductor under the ionizing influence of

[1] The second in a series of three lectures concerning the magnetic field of the Earth and its atmosphere, delivered at the Carnegie Institution of Washington, March 15, 1932.

powerful sunlight. It was known that the chemically active rays of the Sun, near the violet end of the spectrum, are able to ionize air, that is, to break up neutral gas atoms into electrically positive and negative constituents. The radio waves emitted from the sending-station would thus only expand hemispherically, until the ionized conducting-layer was reached, about 100 km above the station. Here they would be reflected back to the ground for repeated reflection upwards; so that the wave would then expand in two dimensions only, like a cart-wheel 100 km thick, the wave advancing radially, along the spokes.

This hypothesis of an ionized layer or layers in the upper air, prognosticated in 1902, was not verified experimentally until Breit and Tuve, at the Department of Terrestrial Magnetism of the Carnegie Institution, photographed in 1925 the arrival of radio echoes from the overhead ionized layer.[2]

Fig. 1, taken from a paper by Appleton,[3] represents diagrammatically a

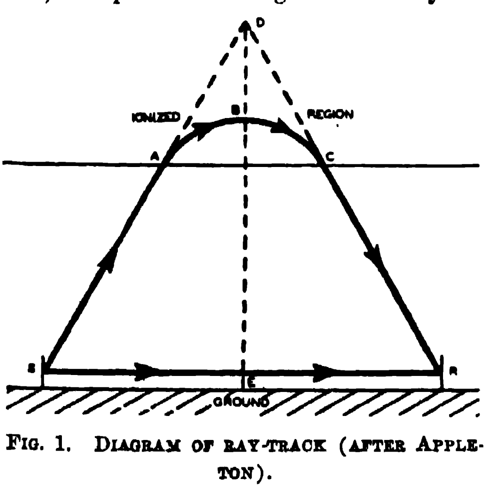

FIG. 1. DIAGRAM OF RAY-TRACK (AFTER APPLETON).

[2] G. Breit and M. A. Tuve, "A Test of the Existence of a Conducting Layer," *Phys. Rev.*, 28, 554–575, 1926.

[3] E. V. Appleton, "Some Notes on Wireless Methods of Investigating the Electrical Structure of the Upper Atmosphere," *Proc. Phys. Soc.*, 41, 43–59, 1928; 42, 321–339, 1930.

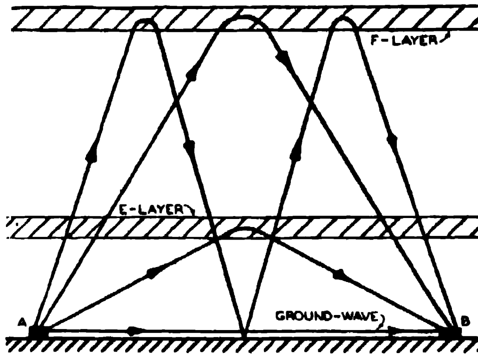

FIG. 2. VARIOUS PATHS BY WHICH PULSE MAY ARRIVE AT RECEIVING-STATION (AFTER GILLILAND AND KENRICK).

radio sending-station *S* and a receiving-station *R*, situated on the ground-level *SER*, say 150 km apart. An outgoing radio impulse, emitted at *S*, reaches *R* over the ground, following the direct horizontal ground-path *SER*. This is called the "ground-wave." At almost the same moment, an upwardly directed ray *SA* reaches the ionized region *ABC*, the lower boundary of which is probably not sharply defined. On entering the region, the ray is bent from the straight path *BAD* into the refraction-path *ABC*, so that emerging from the ionized layer at *C*, it reaches the receiver *R* by the downward line *CR*. The up and down ray *SABCR* will take a little longer to reach *R* than the ground-wave, and will reveal itself as an echo-signal following behind the ground-signal. The observed time of delay will furnish a measure of the apparent height, or virtual height, *ED*, of simple virtual reflection. This virtual height is greater than the actual height of the lower boundary *AC* of the layer, and also greater than the height *EB* reached by the ray before being turned back.

Fig. 2, from a recent paper by Gilliland and Kenrick,[4] indicates two ionized

[4] T. R. Gilliland and G. W. Kenrick, "Preliminary Note on an Automatic Recorder Giving a Continuous Height-record of the Kennelly-Heaviside Layer," *Bur. Stan. J. Res.*, 7, 783–789, 1931.

layers, which Appleton has called the *E*- and *F*-layers, respectively. The *E*-layer is lower, and long radio waves tend to be reflected down to ground from it. Shorter waves can penetrate the *E*-layer, and may then be reflected down by the upper *F*-layer. The sending-station at *A* emits rays in all directions, including those along the ground. The ground-wave *AB* reaches the receiver at *B* by the direct route. A pulse is shown reflected from the lower layer *E*. There will be a certain short delay between the arrival at *B* of the ground-wave and the reflected *E*-wave. Then there is a wave shown which succeeds in passing through the *E*-layer twice, first upwards and then downwards, being reflected from the *F*-layer but not intercepted by the *E*-layer. This *F*-echo ray will have a greater delay than the *E*-echo. Finally, there is a pulse shown which is reflected from the *F*-layer to ground and then back from ground to sky, again reflected from the *F*-layer and reaching the receiver *B* after passing four times, in all, through the *E*-layer. In such a case, the photographic recorder at *B* would show one ground-pulse followed by three echoes, each of which has pursued a different path.

In some tests no echoes are found, and the ground-wave arrives alone. In others, one echo is found, while in yet

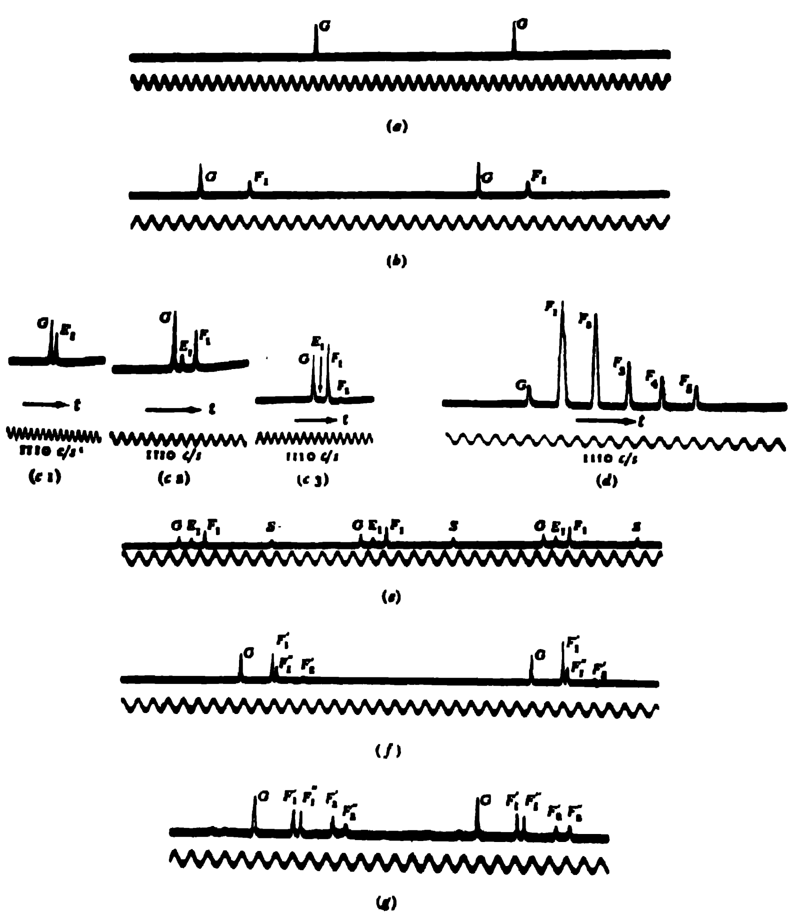

FIG. 3. DIFFERENT TYPES OF REFLECTION (AFTER APPLETON AND BUILDER).

FIG. 4. HEIGHT-RECORD SHOWING GRADUAL RISE OF LAYER FROM 241 TO 399 KM, AND TEMPORARY APPEARANCE OF OTHER LAYERS; RECORD RUNS FROM 5: 30 P. M., JUNE 12, TO 2: 15 A. M., JUNE 13, 1931, FOR FREQUENCY 4,045 KC; THE GROUND-TRACE APPEARS AT BOTTOM OF RECORD (AFTER GILLILAND AND KENRICK).

others there may be six or more. In Fig. 3, which is taken from Appleton and Builder's paper[5] of January, 1932, there are various records of echo-patterns, obtained near London at different times. Time measurements are furnished by the serrated lines below each record, the frequency being given as 1,110 cycles per second; so that the interval between successive serrations is roughly one millisecond (0.0009 sec). The record at (*a*) shows only two successive ground-waves *G*, *G*, emitted about one fiftieth of a second apart, no echoes appearing. At (*b*) there are two records, each showing a ground-wave followed by one echo F_1, attributed to the *F*-layer, and arriving about 4 milliseconds (0.004 sec) later. If the delay were just 0.004 second, it would correspond to an extra length in the echo-path of $300{,}000 \times 0.004 = 1{,}200$ km, or to a virtual layer-height of approximately 600 km. At (c1) there is a ground-wave *G*, followed after about one millisecond by a single echo E_1 assigned to the E-layer. This delay would correspond roughly to a virtual layer-height of 150 km. At (c2) there is a ground-wave *G*, a small echo E_1 of about one millisecond delay from an *E*-layer, and then a larger echo F_1 of about 3 milliseconds' delay from an *F*-layer at a virtual height of about 450 km. At (*c*3) there is one very small *E*-echo and two *F*-echoes F_1 and F_2. At (*d*) there is no *E*-echo visible; but there are no less than four *F*-echoes at sensibly regular intervals. Similar echo-patterns, rather more complex, are given at (*e*), (*f*) and (*g*).

Similar oscillographic records have been made at the Department of Terrestrial Magnetism, by Tuve, Hafstad and Dahl.

Very recently, it has been found possible to obtain continuous photographic records of the virtual heights of the ionized layer or layers, by means of a special apparatus[4] designed for that purpose at the Bureau of Standards, under the direction of Dellinger. Such a record, covering a period of nearly nine hours, is given in Fig. 4. The ground-signals, forming a continuous heavy line, appear at the bottom of the record. There are then two curved lines, more or less parallel, indicating series of reflections from two virtual heights. There are also transient records of intervening layer-reflections. As the virtual height increases, so does the elevation of the corresponding curve from the base of the diagram.

[5] E. V. Appleton and G. Builder, "Wireless Echoes of Short Delay," *Proc. Phys. Soc.*, 44, 76–87, 1932.

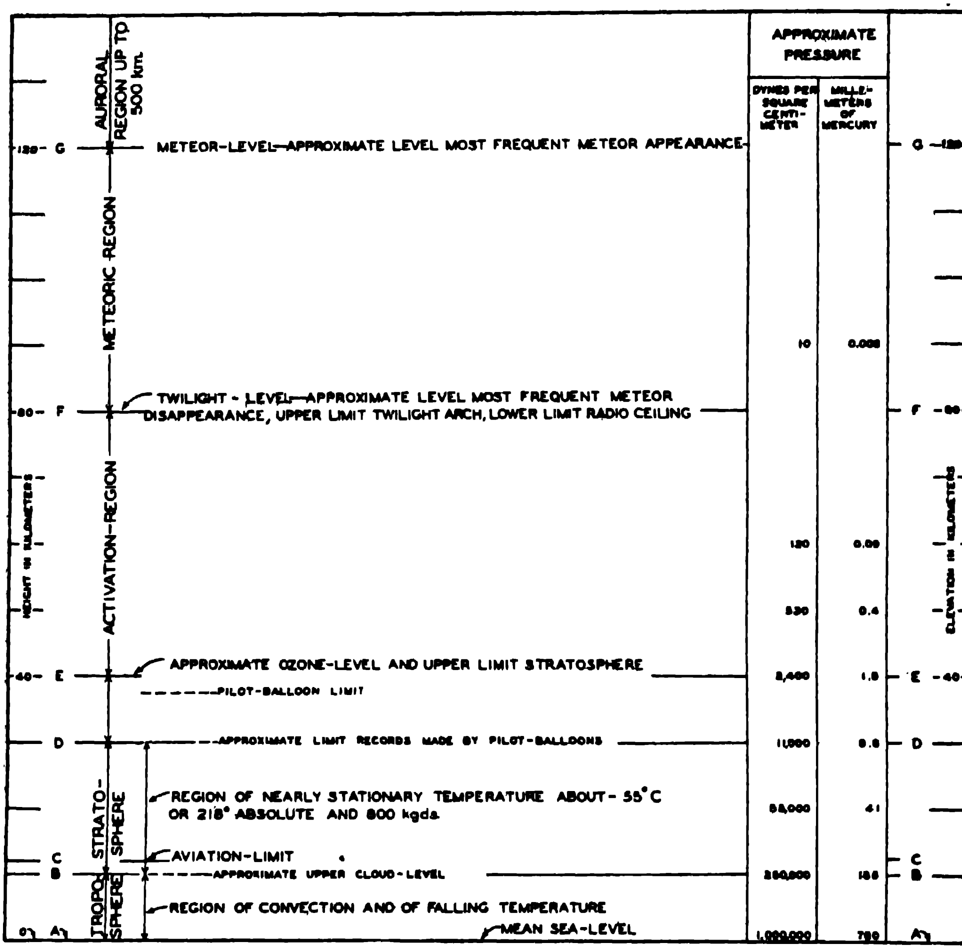

FIG. 5. OUTLINES OF ATMOSPHERIC REGIONS UP TO 120-KM ELEVATION (LEVELS *B*, *E* AND *F* ARE NOT FIXED, BUT ARE STATISTICAL AVERAGES VARYING WITH THE SEASON AND THE LATITUDE).

TROPOSPHERE, STRATOSPHERE, ACTIVATION, METEORIC AND AURORAL REGIONS OF THE ATMOSPHERE

A diagrammatic vertical section of the atmosphere, up to a height of 120 km, is given in Fig. 5, which has been prepared with the kind assistance of Professor Alexander McAdie, of the Blue Hill Meteorological Observatory. Here the bottom line *AA* represents mean sea-level. The level at *B*, 10 km up, gives the approximate upper limit level of clouds in the sky; while the 10-km layer *AB* is described as the *troposphere* or region above which the temperature ceases to fall and begins slightly to rise again. It will be understood that this dividing line between the troposphere and *stratosphere* varies with the latitude of the locality, season of the year and hour of the day, so that the elevation of 10 km is only a rough round number easily remembered. The other levels at *E*, *F* and *G* are likewise only averages.

At or near 12 km, *C* in the diagram, is the approximate limit of aviation height. At *D*, 30 km up, is the approximate limit of elevation from which rec-

ords have been secured by apparatus sent up on "pilot-balloons"; while at 37.5 km we have the limit of non-recording pilot-balloons.

At *EE,* 40 km elevation, we have the approximate upper limit of the stratosphere and the estimated "ozone-level." From *EE* to *FF,* we have an activation region in which ionization is supposed to develop actively during daylight hours. At *FF,* 80 km above the sea, is the twilight level. Near here is the upper limit of the twilight arch in the sky, the most frequent level of meteor disappearance, the lower level of the lower ionized layer or *E*-layer of Appleton's observations, and also the lower limit of auroral displays.

Between the 80-km and 120-km levels *FF* and *GG,* is the meteoric region, in which meteors are most abundantly visible. Above the meteor average appearance—level *GG,* extends the auroral region, and the region of upper ionization up to say 500 km. Above the 30-km level, however, from which direct records have been secured, information concerning the nature and constitution of the upper air is at present necessarily fragmentary and indirect.[6]

Correlation of Long-wave Transatlantic Radio Signal-strengths with Terrestrial-magnetic Fields, and with Sunspots

In Fig. 6 there is seen a plotted series of observations of monthly average radio signal-strengths over a period of seven years (1921–28), emitted by Lafayette station, and recorded (heavy line) at the Bureau of Standards in Washington, by Austin, and (dotted line) at the Meudon Observatory, near Paris, France. The Lafayette station is close to the Bay of Biscay shore, near Bordeaux, France, and its conditions of signal-emission are reported at regular intervals. It will be seen that there is good correlation between these curves, which rise and fall together. These 3 P. M. (Eastern Standard Time) signals are strongest each year in the winter and weakest in the summer months. The ratio of annual low to high is smaller at Meudon than at Washington, D. C. The direct path of transmission is entirely overland to Meudon, across France; while it is almost entirely over the sea, to Washington, across the Atlantic Ocean. Here the annual fluctuations may be partly cosmic, that is, produced by influences outside the Earth's surface, and partly terrestrial, or by influences at or within the Earth's surface; but the effects are similar in both series of observations.

Photographic records of the elements of the Earth's magnetic field, as obtained at Cheltenham, Maryland, have been maintained by the U. S. Coast and Geodetic Survey for many years, and a daily record of the strength of radio signals from several European long-wave radio stations has been maintained by Austin at the Bureau of Standards for 17 years. Austin's comparison between the magnetic activity in magnetic horizontal intensity and radio signal-intensity is presented in Fig. 7. It shows a fair degree of correlation. It is not yet

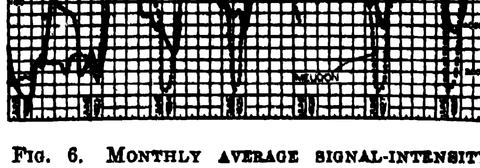

Fig. 6. Monthly average signal-intensity as received from Lafayette station (FYL at Washington and at Meudon, 3 P. M. (after Austin).

[6] Alexander McAdie, "Observations and Investigations Made at the Blue Hill Meteorological Observatory in 1929," Cambridge, 1930.

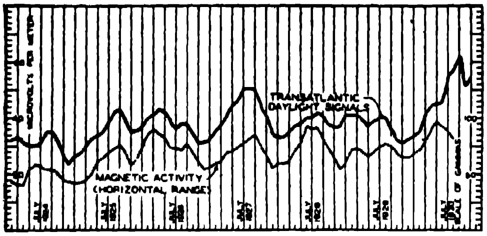

FIG. 7. CORRELATION BETWEEN MAGNETIC ACTIVITY AS INDICATED BY RANGE IN HORIZONTAL INTENSITY AT CHELTENHAM, MARYLAND, AND RECEPTION-INTENSITY OF TRANSATLANTIC DAYLIGHT SIGNALS (AFTER AUSTIN).

clear as to the nature of this correlation. It may be attributable in part to variation in the ionized layer, the radio ceiling over the Atlantic Ocean, or to cosmic influences not yet grasped. In this case, the radio signals were received from Europe in an east-west direction. A similar analysis by Austin for signals from Argentina, received over the Atlantic in a south-north direction, as given in Fig. 8, for the four years 1924–28, seems to show but little correlation; so that apparently the direction of transmission enters into the relation.

A set of curves appears in Fig. 9 for

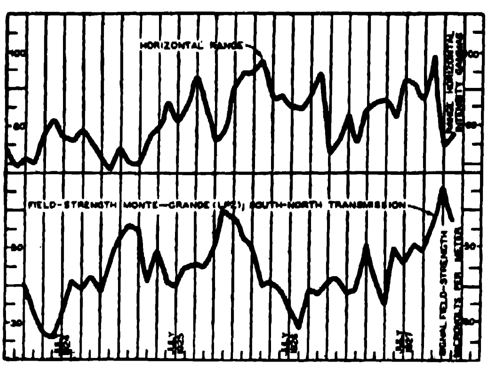

FIG. 8. CURVES OF MAGNETIC ACTIVITY AS INDICATED BY RANGE IN HORIZONTAL INTENSITY AT CHELTENHAM, MARYLAND, AND RADIO SIGNAL-STRENGTH FROM STATION MONTE GRANDE (LPZ) IN ARGENTINA, SHOWING LACK OF CORRELATION ON NORTH-SOUTH RECEPTION (AFTER AUSTIN).

three series of observations—(*a*) radio signal-intensity, averaged from several European stations, as measured at the Bureau of Standards, (*b*) sunspot-numbers and (*c*) the solar radiation-intensity as measured by the Smithsonian Institution, all for a period of three years. Here we have very distinct correlation between the three curves. Some interrelation exists between these solar variations and radio variations. Perhaps it is attributable to the conditions of the ionized layer.

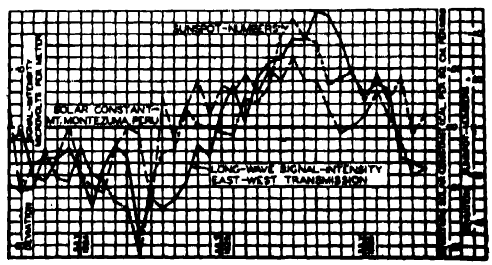

FIG. 9. CORRELATION BETWEEN SUNSPOT-NUMBERS, SOLAR RADIATION AND SIGNAL-INTENSITY AS RECEIVED AT WASHINGTON, 10 A. M. AND 3 P. M., FROM EUROPEAN STATIONS DURING JANUARY, 1924, TO DECEMBER, 1926, AS REPRESENTED BY THE DEVIATION OF MONTHLY AVERAGE FROM 3-YEAR MONTHLY AVERAGES (AFTER AUSTIN).

Fig. 10, from Austin's comparison of monthly averages for radio signal-intensity from two European stations, and for monthly averages of sunspots, is plotted over a six-year period. Here we recognize a general correlation, but without close agreement in detail.

We now come to some comparisons by Pickard (Fig. 11) over an eight-year period 1916–24 between averages of radio signal-intensities from the European station Nauen, as observed at the Bureau of Standards, and terrestrial-magnetic variations. Here again we find a certain degree of evident correlation, although in details the agreement is not close.

Correlation of Sunspots with Radio Signal-strengths of Moderate Wave-length

We have thus far been discussing the relative behavior of long radio waves to sunspots or to terrestrial-magnetic variations. For present purposes, we may definė long waves as waves exceeding one kilometer in length. We may now consider the behavior of moderately long radio waves (100 meters to 1,000

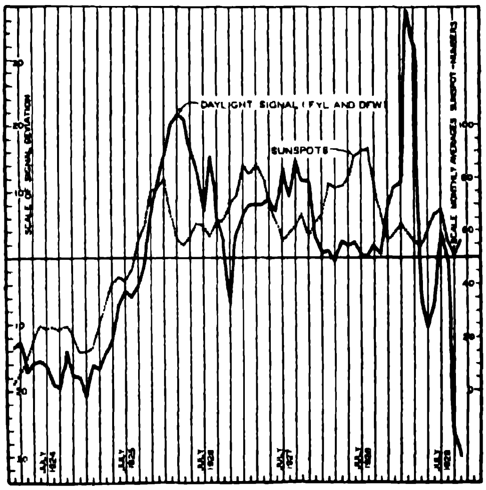

Fig. 10. Signal deviations of monthly signal-strength from 6-year monthly averages compared with monthly averages of sunspot-numbers, January, 1924, to October, 1929 (after Austin).

meters). American broadcasting-stations employ moderately long waves (200 meters to 550 meters). Pickard and Stetson have made records of the radio carrier-wave intensity from certain broadcasting-stations, and have compared them with sunspot-numbers during the same period. Fig. 12 is a diagram given by Stetson, of the Perkins Astronomical Observatory, for the evening radio reception from station WBBM of Chicago, plotted upwards during the three years 1926–28, and for the sunspot-numbers plotted downwards during the same period. Here a distinct inverse correlation is indicated. Similar results have been reported by Stetson during a more recent period.

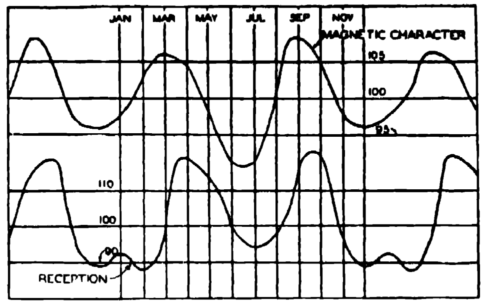

Fig. 11. Monthly averages of magnetic character of day and Washington day reception from station POZ, 1916 to 1924 (after Pickard).

Diurnal Range of Virtual Height of Ionized Layer on Magnetically Quiescent Days

It is found that the virtual height of the ionized layer for short waves, that is, waves of from 10 meters to 100 meters in length, goes through a fairly regular diurnal variation in the absence of magnetic storms or perturbations. In general, the height is lower during daylight than during darkness, although the conditions vary in detail with the season and the locality. An explanation for this observed condition is suggested by the fact that during sunlit hours the upper air is exposed to active ionization by the Sun's rays, especially at the violet end of the spectrum; so that the number and den-

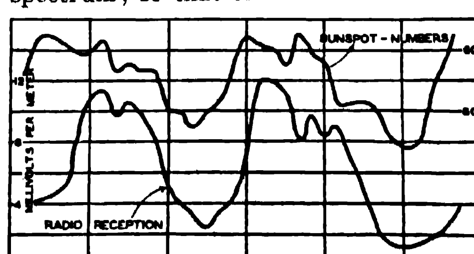

Fig. 12. Correlation between sunspot-numbers and signal-intensity, 1926 to 1928 (after Stetson).

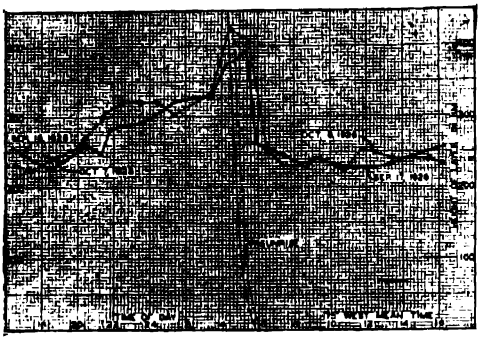

FIG. 13. DIURNAL VARIATION IN HEIGHT OF THE KENNELLY-HEAVISIDE LAYER ON TWO DAYS, SEPTEMBER 16–17 AND OCTOBER 7–8, 1928, FOR WAVE-LENGTH OF 70 METERS (AFTER TUVE, HAFSTAD AND DAHL).

sity of free electrons considerably increase, thus bringing the ionized layer lower. At night, on the contrary, neutralization of the gas atoms tends to occur, by the attraction between free electrons and ions.

Fig. 13 shows the range of virtual heights observed at the Department of Terrestrial Magnetism of the Carnegie Institution of Washington, for waves of 67.5-meter length, on two different days (September 16 and October 7, 1928). During the daytime the virtual height of the ionized layer was about 225 km; but this increased at night to about 400 km just before sunrise.

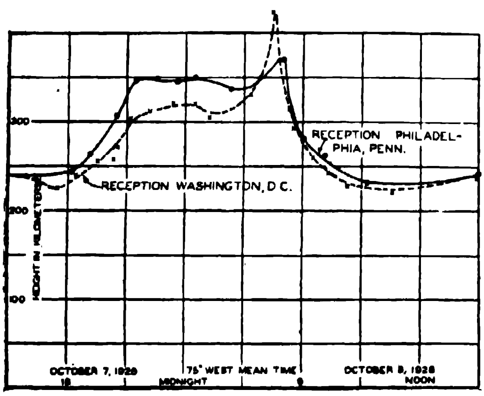

FIG. 14. VIRTUAL HEIGHTS OBSERVED OCTOBER 7–8, 1928: (*a*) AT MOORE SCHOOL OF ELECTRICAL ENGINEERING IN PHILADELPHIA, PENNSYLVANIA, (*b*) DEPARTMENT OF TERRESTRIAL MAGNETISM, WASHINGTON, D. C., ON TRANSMISSION FROM NAVAL RESEARCH LABORATORY, WASHINGTON, D. C., ON 4,435 KC (AFTER KENRICK AND JEN).

A pair of curves of diurnal layer-height appear in Fig. 14 for the day October 7–8, 1928, as observed concurrently at two different American receiving-stations. The waves of 67.5-meter length were emitted at the Bellevue Naval Research Laboratory, near Washington, D. C. The heavy curve shows the virtual heights as measured by Kenrick and Jen at the Moore School of Electrical Engineering in Philadelphia,

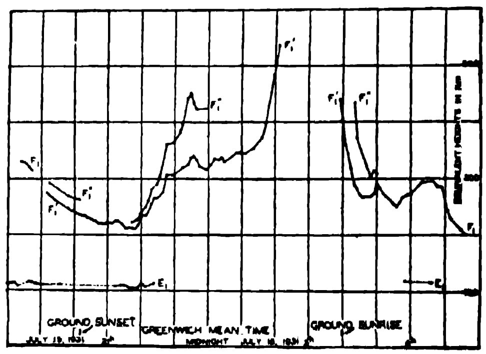

FIG. 15. LAYER-HEIGHTS AT DIFFERENT HOURS (AFTER APPLETON).

while the dotted line shows the heights measured at the Department of Terrestrial Magnetism, Washington, D. C., by Tuve, Hafstad and Dahl. The two curves are in good conformity. The daylight height was about 225 km and the darkness height about 400 km before sunrise.

Fig. 15 is taken from a recent paper by Appleton. It represents the virtual layer-heights measured at King's College, London, for waves of 80-meter length, during the day July 15–16, 1931, emitted from a sending-station in East London. Appleton points out that, during part of the time, reflections were obtained from the *E*-layer at a height of

about 110 km, as well as from a higher F-level. During the night, however, the E-reflections disappeared and the virtual height of the F-level rose to 500 km, when finally this layer disappeared until about sunrise.

A radio wave emitted near the ground from a simple vertical mast antenna is observed to be plane polarized, that is, its electric flux oscillation is in a vertical plane (following the electric current oscillations in the antenna); while the associated magnetic flux oscillation is in the horizontal plane of the ground.

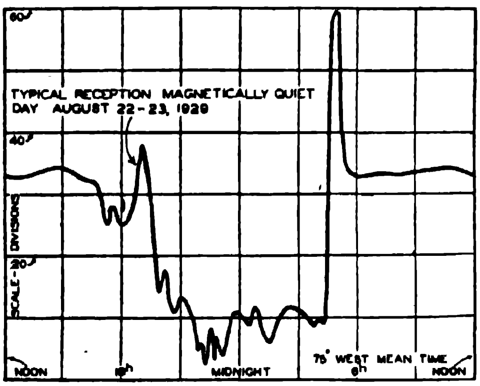

FIG. 16. TYPICAL RECEPTION FROM TUCKERTON (WCI) AT NEWTON CENTER, 16-KM WAVE, ON MAGNETICALLY QUIET DAY, AUGUST 22–23, 1929, SHOWING MARKED SUNSET AND SUNRISE PEAKS AND LOW NIGHT FIELDS (AFTER PICKARD).

Appleton finds that when such a wave passes through an ionized layer in a direction roughly parallel to the Earth's local magnetic field, the wave tends to split into two rotary polarized components, one right-handed and the other left. In the northern hemisphere, the right-handed component is retarded and absorbed by the layer more than the left; so that the received descending wave is found to be circularly polarized with left-handed rotation. In a recent[7] communication, he has described experiments

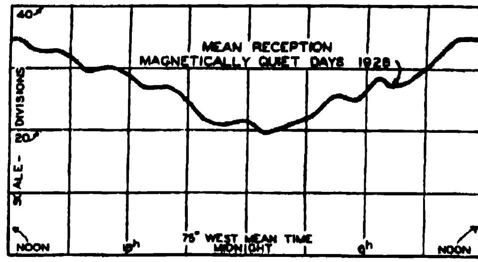

FIG. 17. TYPICAL RECEPTION FROM TUCKERTON (WCI) AT NEWTON CENTER, 16-KM WAVE, FOR THE MEAN OF MAGNETICALLY QUIET DAYS IN 1928 (AFTER PICKARD).

made in Australia, not remote from the magnetic pole of the southern hemisphere, and there the reflected wave has been found to possess right-handed circular polarization. Perhaps the two F-layer reflections in Fig. 15 correspond to the two rotary components into which the initial wave may be this decomposed.

EFFECTS OF MAGNETIC STORMS ON LONG-RANGE RADIO SIGNAL-RECEPTION

It is found that magnetic storms, as recorded in terrestrial-magnetic observatories, are not only apt to be accompanied by powerful stray currents in the crust of the Earth and by auroral displays in the upper air, but also by marked disturbances in radio signals, although the effect produced differs with the length of the radio waves.

Fig. 16 is a graph given by Pickard of diurnal signal-strength received at Newton Center, Massachusetts, on fairly

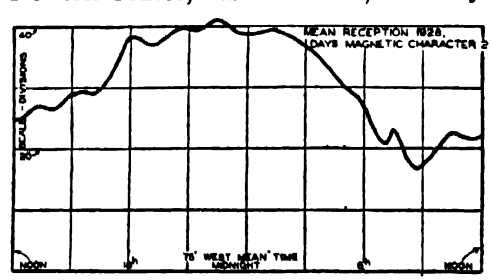

FIG. 18. TYPICAL RECEPTION FORM TUCKERTON (WCI) AT NEWTON CENTER, 16-KM WAVE, FOR THE MEAN OF DAYS OF MAGNETIC CHARACTER 2 DURING 1928 (AFTER PICKARD).

[7] E. V. Appleton, "Polarization of Downcoming Wireless Waves in the Southern Hemisphere," *Nature*, 128, 1037, 1931.

long radio waves emitted from the Tuckerton Station WCI, during a single magnetically quiescent day, August 22–23, 1929. Here the received intensity is fairly steady during the day, falls to a somewhat irregular low value at night, and shows sudden peaks near sunrise and sunset.

Pickard's corresponding graph for average reception during six months at and from the same stations on days of moderately quiet magnetic conditions appears in Fig. 17. There is now relatively little difference between day and night signal-intensity. The peaks have disappeared.

The conditions of diurnal average reception for days of magnetic disturbances or moderate magnetic storms are given in Fig. 18. Here the received signal-intensity at Newton Center is greater at night than by day, or there is a reversal of the quiescent conditions. Finally, Fig. 19 is Pickard's graph for reception-conditions during the severe magnetic storm of July 8–9, 1928. Here the signal-intensity is very distinctly greater during the night than during daylight hours, showing a marked inversion of the conditions existing on magnetically quiet days.

In Fig. 20 we have some graphical analyses reported by Anderson, of the American Telephone and Telegraph Company, for the radio signal-intensities of long transatlantic waves, in the year 1927. The central line of each diagram represents the onset of the storm, and

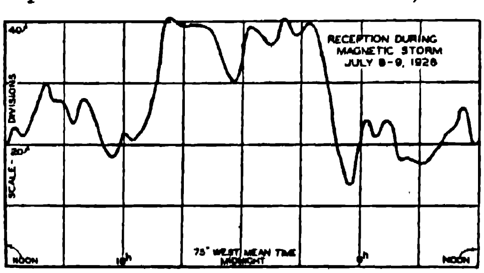

FIG. 19. TYPICAL RECEPTION FROM TUCKERTON (WCI) AT NEWTON CENTER, 16-KM WAVE, DURING SEVERE MAGNETIC STORM JULY 8–9, 1928, SHOWING MARKED INVERSION (AFTER PICKARD).

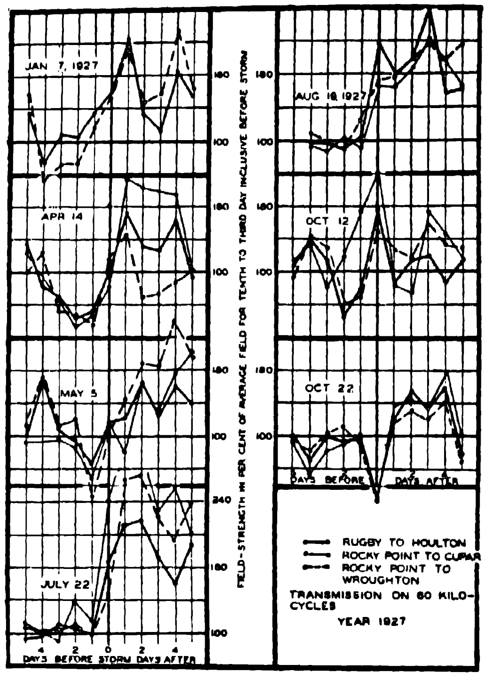

FIG. 20. EFFECT OF SOLAR DISTURBANCES ON 60-KCS DAYLIGHT RADIO TRANSATLANTIC TRANSMISSION IN 1927, SHOWING CORRELATION OF LONG-WAVE RADIO RECEPTION AND MAGNETIC STORMS (AFTER ANDERSON).

seven storms are separately considered. The mean signal-strength is plotted for each of the five days before and after the storm, on three distinct radio transmissions. The curves tend to show that for these long waves (5 km), the signal-strength increased distinctly for a few days after a storm.

A similar result is reached in Fig. 21, which represents an analysis by Austin and Wymore for the signal-strength received at the Bureau of Standards during the years 1925–27 from several long-wave European stations. The deviations attributable to magnetic storms are plotted for five days before and after the onset. There is a distinct rise in signal-strength following a storm, reaching a maximum in about two days and falling back to normal in about three days more.

On the other hand, the effect of a magnetic storm on the reception of short radio waves crossing the Atlantic, seems to weaken them greatly. Anderson's analysis of the effect of a magnetic storm on July 8, 1928, appears in Fig. 22. The thin broken line indicates the variation in the horizontal component of the Earth's magnetic field; while the heavy line indicates the strength of short-wave radio transmission from Deal, New Jersey, to New Southgate in England. These two lines follow together remarkably. They show a falling off in radio reception commencing two days before the center of the storm, reaching a minimum at the time of greatest magnetic disturbance, and returning to normal after about six days. At the same period, the long-wave radio signals (5,000 meters) from Long Island, New York, to Cupar in Scotland, increased instead of dwindling, during and after the storm.

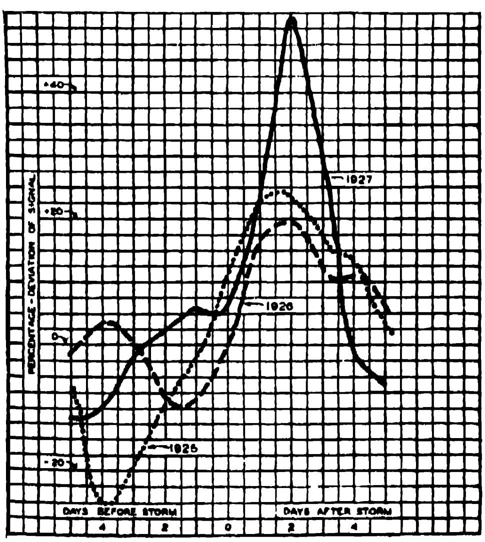

FIG. 21. AVERAGE DAILY DEVIATION FROM MONTHLY MEAN OF DAYLIGHT FIELD-STRENGTH OF SIGNALS FROM STATIONS IN EUROPE DURING PROGRESS OF MAGNETIC STORMS 1925, 1926, 1927 (AFTER AUSTIN AND WYMORE.)*

* Note correction in Fig. 21: The dotted-line curve should be dated 1926, and dashed-line curve 1925.

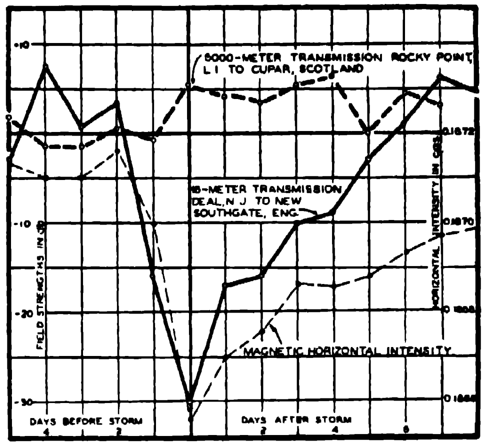

FIG. 22. VARIATION IN RADIO TRANSMISSION FOR 16-METER AND FOR 5,000-METER TRANSATLANTIC SIGNALS, SHOWING CORRELATION WITH MAGNETIC STORMS (AFTER ANDERSON).

Although there is little known, as yet, concerning the influence of magnetic storms on radio wave-transmission, yet the suggestion has been offered by several observers that during magnetic storms there is likely to be an increase in the depth and density of the ionized layer. This tends to improve the reflection and transmission of long waves. On the other hand, the short waves which are supposed to be reflected back to ground from higher levels, are likely to suffer excessive attenuation, by absorption in the lower layers.

SUNSPOT-CYCLES AND CYCLES OF TERRESTRIAL-MAGNETIC ACTIVITY

That there is a clear correlation between sunspot-cycles and cycles of the Earth's magnetic activity is borne out by Fig. 23, which compares annual sunspot-numbers with corresponding annual magnetic activity, as tabulated at the Department of Terrestrial Magnetism, over the period 1834–1930 or nearly 100 years. The upper curve follows the magnetic activity, and the lower the sunspot-numbers. Although the details of these curves often differ, yet the general agreement is remarkable. There appear to have been 8 com-

plete cycles of each of these two curves, between the peaks of 1837 and 1928, or an average of about 11.4 years per cycle. Why the Sun should exhibit an eruptive habit of this period is still mysterious. It has been suggested that possibly both series of phenomena may be concurrent symptoms of cosmic influences even more remote than the Sun. At the present date (1932), we are descending to an expected minimum of both sunspots and magnetic activity due in or near 1934.

Two theories have been advanced for the correlation between spots on the Sun with magnetic changes, as well as ionized-layer and radio disturbances on the Earth. These two theories are perhaps not mutually exclusive. One emphasizes the ejection of finely divided matter from the surface of the Sun in jets, which move outwards at high speeds, and, if favorably directed, may reach the Earth's atmosphere in such a manner as to set up strong electric currents, auroral discharges, ionization, etc. The other emphasizes the action of ultra-violet light emitted from the sunspots and the ionizing influence[8] of this actinic radiation on the Earth's atmosphere.

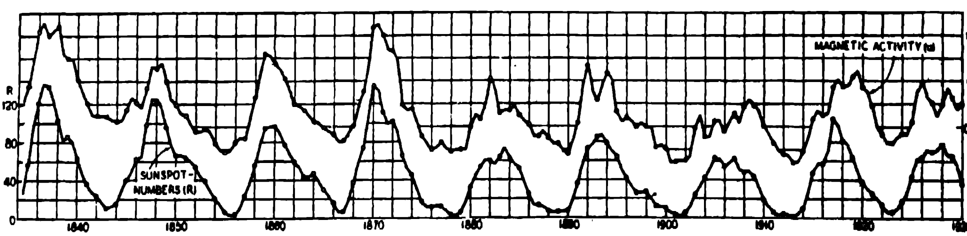

FIG. 23. CORRELATION BETWEEN SUNSPOT-NUMBERS AND MAGNETIC ACTIVITY, 1836 TO 1930 (AFTER DEPARTMENT OF TERRESTRIAL MAGNETISM).

RADIO ECHOES OF LONG DELAY

In 1927–28, Störmer and Hals announced the discovery[9] in Oslo, Norway, of radio echoes following short-wave signals (31.4 meters) emitted from a sending-station at Eindhoven in Holland. These delayed echoes have since been recognized by various other observers, although they seem to be very rarely detectable in European latitudes (35°–60° north). The delay of echoes recorded oscillographically from the ionized layers of the upper atmosphere is ordinarily from about 1 to 4 milliseconds. The delayed echoes, here considered, have been reported as following the generating-signal by an interval of from 1 to 30 seconds, a totally different order of magnitude. A great many of such delayed echoes were reported by J. B. Galle, at the island of Pulo Condore[10] in the tropics, during a French expedition to observe a solar eclipse which was total at that locality in May, 1929.

Two theories have been suggested to explain these extraordinary radio echoes. One was that the signal-ray penetrated the space between upper and lower ionized atmospheric layers, became greatly slowed down in group-velocity, oscillated to and fro between the layers, and finally returned to the ground after great delay. Pederson has shown that this theory is very unsatisfactory, for several reasons.

The other theory, put forward by Störmer, is that when cathode-rays

[8] E. O. Hulburt, "Tables of the Ionization of the Upper Atmosphere," *Phys. Rev.*, 39, 977–992, 1932.

[9] Carl Störmer, "Short-wave Echoes and the Aurora Borealis," *Nature*, 122, 681, 1928; also "Ueber die Probleme des Polarlichtes," Ergebnisse der kosmischen Physik, 1, 1–86, 1931.

[10] J. B. Galle, "Observations relatives à la radioélectricité et à la physique du globe faites à l'occasion de l'éclipse totale de soleil du 9 mai 1929 à Poulo Condore (Indo-Chine)," *Onde Électrique*, 9, 257–265, 1930.

emitted by the Sun move towards the Earth there is, for a given stream-velocity, a certain radial distance from the Earth which they can not enter in a straight line, being deflected by the Earth's magnetic field. Under the influence of this field, the cathode-ray stream would carve out a toroidal hollow space, shaped like an apple, coaxial with the Earth's magnetic polar axis. The ionized walls of this toroidal space, at a radial distance of perhaps two millions of kilometers from the Earth, would be capable of acting as an ionized layer and of reflecting the waves back to the Earth, which is at the center of the tore. A short-wave radio signal capable of penetrating and emerging from the atmospheric ionized layer, would proceed as a straight ray to the toroidal surface, and when reflected back to the Earth, would make a journey of say 4,000,000 km, which would occupy about 13 seconds. Different velocities and masses of ionized streams, approaching the Earth, could set up toroidal reflectors at different distances.

Many more observations will be necessary to confirm or refute this ingenious theory of long-delayed echoes. Fig. 24, from one of Störmer's publications, indicates the incoming electronic streams descending to the Earth in curtain-like sheets around the Earth's magnetic poles, and forming, under favorable conditions, visible auroral clouds.

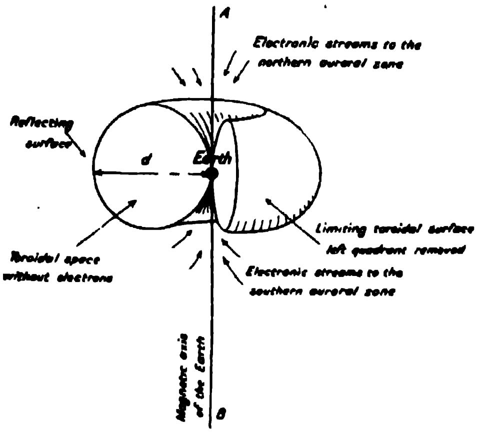

FIG. 24. DIAGRAMMATIC SKETCH OF THEORY FOR LONG-DELAYED ECHOES (AFTER STÖRMER).

CONCLUSIONS

It is evident that there are widespread cosmic influences which affect the magnetic field, auroras, the ionized air-layer and radio signals, at or near the surface of the Earth. Within the last few decades, radio has become available as a new research tool for exploring the upper air all round the world. The conjoint organization of a man directing a locomotive or an airship is a creative combination of much larger powers and radius of action than the same man unarmed. Since a properly equipped operator at a powerful radio station can invade the atmosphere up to say 200 km, the height of the ionized layers, all round the world, the conjoint organization of operator and radio becomes a spherical combination 40,000 km around, hollow, and 200 km thick. Moreover, if Störmer's theory of delayed echoes should be confirmed, the same operator, armed with radio waves, would become a conjoint organization with a toroidal sphere of influence having a radius of more than a million kilometers. In any event, careful study of radio wave-phenomena should enable the upper atmosphere to be explored to elevations that have heretofore been inaccessible to man.

In a certain sense, it is fortunate that the relations between radio wave-propagation and the various cosmic phenomena here considered, are so complex. If radio waves of all lengths were subject to one and only one simple law of transmission in passing through the Earth's atmosphere, the law might be easy to determine, but it could not be expected to elucidate the behavior of

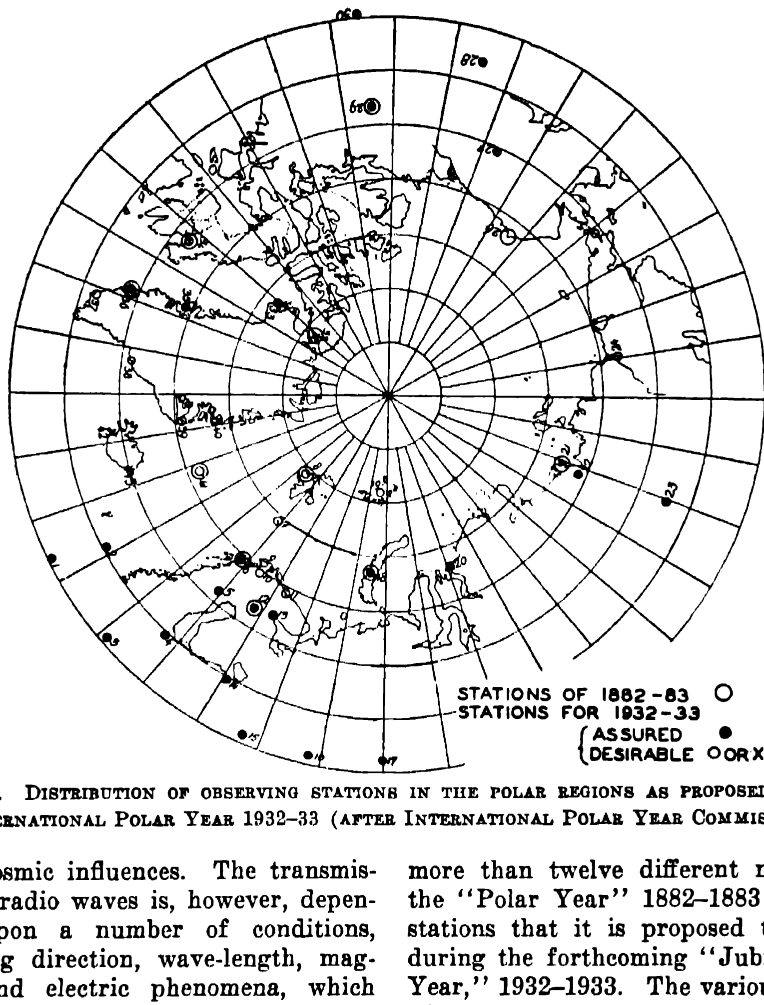

FIG. 25. DISTRIBUTION OF OBSERVING STATIONS IN THE POLAR REGIONS AS PROPOSED FOR THE INTERNATIONAL POLAR YEAR 1932–33 (AFTER INTERNATIONAL POLAR YEAR COMMISSION).

other cosmic influences. The transmission of radio waves is, however, dependent upon a number of conditions, including direction, wave-length, magnetic and electric phenomena, which make the problem more difficult, but promise much collateral information when it is finally solved.

Fig. 25 is a map of the northern polar hemisphere prepared by the International Polar Year Commission to show the magnetic stations that were occupied successfully by expeditions from more than twelve different nations in the "Polar Year" 1882–1883; also the stations that it is proposed to occupy during the forthcoming "Jubilee Polar Year," 1932–1933. The various nations will carry out a concerted program of meteorological, magnetic, electric and radio work, which should lead to the acquisition of much needed knowledge in all these directions. It can not be doubted that all such knowledge will lead to results of international importance and utility.

CARBONATION OF DAIRY PRODUCTS

By Professor M. J. PRUCHA

DEPARTMENT OF DAIRY HUSBANDRY, UNIVERSITY OF ILLINOIS

UNDER ordinary conditions, carbon dioxid is a gas; when compressed under a high pressure it is changed into a liquid; and when subjected to a low temperature of about 150 degrees F. below zero it is changed into a solid. In this latter condition it is known as "dry ice." It is readily soluble in water. The amount of it that can be dissolved in water depends on the temperature of the water and on the pressure under which the water is held. When it is dissolved in water or in beverages, it imparts to them a pleasant pungent taste which is greatly relished by some people. Carbonated beverages are well-known articles of commerce.

Carbon dioxid could be classed as a preservative and a mild germicide. If enough of it is dissolved in a beverage, it will stop the bacterial multiplication therein and thus will prevent the deterioration and the spoilage of the beverage. If the amount of carbon dioxid is further increased so that a pressure is produced in the sealed container, it will not only stop the bacterial multiplication but will also destroy most of the bacteria in the beverage. To bring about this result in soft drink beverages, it is necessary to carbonate them at a pressure of about seventy pounds. Here, also, it might be added that the carbonated beverages seem to possess a certain medicinal value for the digestive system.

In the dairy industry the loss due to the deterioration in quality and to the spoilage of milk and milk products is very great. An effective sanitary control of milk and milk products has been, and still is, an important and puzzling public problem. If the carbonation of soft drink beverages prevents their spoilage, makes them more sanitary and gives them a desirable flavor, will it also impart the same or similar benefits to milk and milk products? An answer to this question was sought in the experiments conducted in the dairy bacteriology laboratories of the department of dairy husbandry of the University of Illinois. From these experiments the following conclusions were reached.

The fluid dairy products such as fresh milk, evaporated milk, cream, ice-cream mix, and various milk drinks can be carbonated in two different ways.

One method consists in dissolving carbon dioxid in the dairy products until a saturation point is reached and then storing the products in the usual dairy utensils such as milk cans which can not be sealed air tight. The carbon dioxid under these conditions gradually escapes. This manner of carbonation tends to prolong the keeping quality of the products but does not prevent the deterioration or the spoilage of the products. The length of time that a dairy product so carbonated can be kept before spoiling depends on the temperature at which it is kept and on the number and kind of bacteria present in the product before it is carbonated. Many of the acid-producing bacteria are able to grow in presence of carbon dioxid. When the dairy product is pasteurized at a temperature of about 170 degrees F. so as to kill the acid-producing bacteria and is then carbonated, its keeping quality will be materially prolonged. For example, evaporated milk carbonated and stored in milk cans in a refrigerator at a temperature of about 40 degrees F. remained in an excellent condition for a month, while the same milk, not carbonated but kept under the same conditions, spoiled in two weeks.

This manner of carbonation will prob-

ably not be practical for the preservation of fluid sweet milk. It could, however, be used with profit for evaporated milk and for ice-cream mix. These two products are prepared at the source of milk supply and may be transported long distances or stored for future use. The carbonation of these products as soon as they are made would materially improve their keeping quality.

The other method of carbonation of fluid dairy products is carried out by putting the product in an air-tight strong container and then introducing enough carbon dioxid to produce a pressure in the container. Milk can be preserved in the same manner as are the soft drink beverages, except that a much higher pressure is required.

In one experiment milk of good quality was carbonated under a pressure of 180 pounds and then was stored for one month at 45 degrees F. This manner of carbonation completely inhibited all bacterial multiplication during the storage period and it also killed most of the bacteria that were present at the start so that the milk became practically sterile. There are certain difficulties involved in carbonation of milk in this manner. It could, however, be utilized in connection with the transportation of fresh milk for long distances, such as ocean voyages.

The carbonation of milk drinks, such as chocolate milk and milk drinks prepared by adding various kinds of flavors to the milk, deserves special attention. In the first place the pungent taste due to carbon dioxid seems to improve the taste of these milk drinks, and secondly the carbonation, if done properly, will materially prolong their keeping quality. The best results from the standpoint of flavor were obtained when the drinks were carbonated in sealed bottles to a pressure of about 40 pounds. These milk drinks could also be put up in the ordinary milk bottles after being carbonated. In this case a much smaller amount of carbon dioxid can be put into the milk and it tends gradually to escape from the bottled milk so that the benefits due to carbonation are not so lasting as when carbonated in sealed bottles.

Experiments were also conducted with solid dairy products, such as butter, cheese, and powdered milk. The method of carbonation of these products consisted in storing the products in the atmosphere of carbon dioxid in an air-tight container. Butter so treated and then stored in cold storage did not deteriorate in quality so soon as similar butter kept under the same conditions except that it was in the air instead of carbon dioxid. It was also noticed that the mold which frequently spoils the butter did not grow in carbon dioxid and that the off-flavors which are due to the oxidation of certain ingredients of the butter did not seem to develop.

The same thing was true of cheese and of powdered milk, namely, that the undesirable flavors that develop as a result of oxidation were largely inhibited by the carbon dioxid. It should also be observed that when cheese was stored in carbon dioxid atmosphere in a sealed container it did not mold. It is a common observation that cheese may spoil very readily owing to the rapid growth of mold on its surface. This fact has seriously interfered with the packaging of cheese for retail trade. Putting up small packages of cheese in sealed containers in carbon dioxid atmosphere might help to solve the packaging of good cheese and might increase the cheese consumption.

Considering all the phases of the problem of carbonation of dairy products, it might be concluded that carbonation of some dairy products is feasible, that it improves their taste, their keeping quality, their sanitary quality and that it might be financially profitable. Carbonation of certain dairy products is not practical nor would it be financially profitable.

SHADE TREES THREATENED BY INSECT PESTS

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EARLY last August a severe wind storm, a near tornado, brought ruin and destruction to many trees in Westport and Fairfield, Connecticut. Large trees were uprooted and those securely anchored to the soil suffered the loss of good-sized limbs. These latter were twisted off and their condition suggested the work of a mighty giant. Something like 2,500 trees were damaged by this storm, and the loss could easily be placed at a quarter of a million dollars. Trees were wrecked in the thickly settled village as well as in the more open country, and those familiar with the situation pronounced it a tragic loss. There is no question but that such was the case. It was a cause for thanksgiving that no lives were lost.

The sudden sweep of the elements and the speedy destruction of thousands of trees capture the human imagination. It is a newspaper story. Every one is interested. There is not the same news value in insect depredations and yet these latter may easily exceed in magnitude and loss the damage resulting from a number of storms, such as the one we have briefly described.

The seriousness of the insect situation in relation to shade trees in the northeastern United States was brought to attention very forcibly last summer. Yet it had not attracted any great amount of notice either from individuals or the press. It is more than probable that comparatively few realize what has actually occurred. Furthermore, it is difficult to get at precise data in relation to this. It is a matter of great importance, so far as our shade trees are concerned, because the effect of the injuries last season will continue to be felt for several years and may produce a very marked change in the shade tree situation. Three insects in particular have caused what might be classed as major damages to shade trees in the northeastern United States. These are the elm leaf-beetle, the Japanese beetle and the European willow-leaf beetle. Who knows how many trees have been affected and the probable outcome?

Estimates made last summer indicate that approximately 100,000 elms in southern Connecticut were seriously damaged or entirely defoliated by the elm-leaf beetle. As many more were seriously injured in the other New England states and some 250,000 in New York State. The Insect Pest Survey of the United States Department of Agriculture recorded serious injury last year by this insect from the New England States and also from New York, Delaware, Maryland, Virginia, Ohio and Kentucky, and from the Far West, namely, Oregon and California. There must have been, surely, at least 200,000 trees in the areas not previously included which were seriously affected by this pest. This brings the estimated total of seriously damaged elms in the northeastern United States to 650,000. These estimates take no account of the trees on private property. These latter would easily equal in number those upon the streets and highways, and the presumption is that an equal number were severely damaged. This brings the grand total of elms seriously damaged last year by the elm-leaf beetle to over one and one quarter million, namely 1,300,000 trees. This is surely a tre-

mendous levy upon the vigor and vitality of one of the most valuable and highly prized of our shade trees. The probabilities favor as much if not more damage the coming season. Communities which suffered severely from elm-leaf beetle last summer may well take warning. The wide-spread injuries by this pest in the Hudson River Valley early in the century resulted in the death of many valuable trees and, as a consequence, communities in that area were practically forced to adopt systematic control measures. Is it too much to hope that the experience of 1931 will result in better protection for the trees in many other localities?

This by no means completes the shade tree story for last year. Those who had occasion to travel in the generally infested Japanese beetle area in 1931 could hardly have failed to note the very general defoliation of trees in a section centering approximately on Philadelphia and extending south to Wilmington, Delaware, and north to Trenton, New Jersey, or thereabouts. It would seem entirely within probabilities that at least a quarter of a million trees may have lost their foliage as a result of the work of this destructive insect. The pest is a general feeder. It shows a marked preference for horse chestnut, linden, elm, willow, apple, peach, sweet cherry, plum, rose, grape, Boston ivy and Norway maple, to mention some of the trees and vines upon which it feeds most readily.

The situation in regard to the Japanese beetle is somewhat different from that in relation to the elm-leaf beetle. This more recent pest attacks a considerable variety of trees and shrubs. It is erratic in its habits. It is spreading rapidly in spite of governmental efforts to check dissemination. The serious damage to shade trees and ornamentals of the generally infested area is destined to be spread over the sparsely infested area which now takes in parts of Virginia, Maryland, Delaware, Pennsylvania, all New Jersey, the southern part of New York, all Connecticut and Rhode Island and two good-sized areas in Massachusetts. These are not the ultimate limits. They simply represent the recorded distribution of this insect to date. The available information indicates the Japanese beetle is controlled fairly well under average horticultural conditions, since the spraying necessary to protect fruit trees from various insect pests ordinarily controls this insect satisfactorily. Such is not the case with ornamentals. It usually means an additional spray and the repeated defoliations, with the inevitable extension of these areas, raises a serious problem.

The third insect in this deadly trio is the European willow-leaf beetle. It is now widely distributed in southern New England, New York and south to New Jersey, Pennsylvania and Maryland. Fortunately, in one respect, the willow does not occupy a very important place as a shade tree. Yet it is somewhat generally grown, and in many sections of the infested area it has been severely damaged by this recently introduced pest. The number of willows defoliated in the eastern United States in 1931 were approximated at 200,000, though it must be admitted that this is a tentative estimate. The willow leaf beetle produces three generations annually, and when conditions are favorable largely prevents the foliage from functioning. The inevitable result is that the trees are weakened. They are certainly far from beautiful when the leaves are changed throughout most of the summer from a bright green to a hideous gray. The situation is made even more serious, so far as the willow is concerned, by the recently discovered willow scab fungus and the very general infection, serious injury and killing of many trees in New England at least.

In addition to the above, the beautiful larch suffered greatly the past summer from the depredations of the larch case bearer. The foliage of this tree was partly to mostly destroyed in southern New England north into the Berkshires of Massachusetts, New Hampshire and probably Vermont, and in corresponding areas in New York State, including extensive tracts in the Adirondacks. A large proportion of these larches were forest trees and yet there must have been many thousands, probably 250,000, which could be classed as ornamental or shade trees. Here again, timely spraying would have prevented serious damage.

Summarizing, it may be stated that insect depredations on shade trees in 1931 affected some two million trees, and this damage was caused by four introduced insect pests. Most of the trees affected were handsome specimens. Some stand upon the lawns of magnificent estates. Not a few are highly prized for sentimental reasons. These trees might easily be worth an average of $100 each. Their total value may thus be placed at $200,000,000. These extended depredations occurred without exciting any great amount of apprehension. No one has suggested that it might be due to the depression. Even tree owners gave it comparatively little attention. The statements of tree experts in not a few cases have been disregarded, possibly because it was thought that their representations were dictated by personal interest. On the other hand, no men are better qualified to pass upon the probabilities in regard to insect depredations than those who are giving their entire time to shade tree welfare. As a scientist interested in the proper solution of this problem, the writer wishes to call attention to the effects likely to result from this situation.

In the first place it must be admitted that a comparison between 2,500 trees damaged by a storm early in August, 1931, in southern Connecticut with the presumably two million trees defoliated by various insects, suggests that the latter may be much more serious than the former, so far as the welfare of shade trees is concerned. We would not belittle the storm damage. That was very severe. On the other hand, defoliation or destruction of the leaves means serious injury, and it was the fate of a vastly greater number of trees.

What is the probable outcome of this extensive defoliation?

In the first place, if we go back to the early part of this century and scan the history of the elm-leaf beetle in the Hudson River Valley, it will be noted that very serious damage was recorded in some communities and this was representative of many other localities. In the cities of Albany, Troy and Watervliet, it was estimated then that fully 4,000 trees had been destroyed by the pest. These were magnificent shade trees. They succumbed after several successive years of defoliation. Observations at that time indicated that the loss of foliage three successive seasons practically ruined trees, and in the case of those with a reduced vigor was frequently followed by death. The extensive studies of earlier years on the gipsy moth in eastern Massachusetts resulted in similar conclusions in relation to various shade and forest trees. A number of communities which suffered most severely from elm-leaf beetle in those earlier days took the lesson to heart and made more or less adequate provision for the protection of the trees. It was about this time that a number of the other communities in the northeastern United States took steps in this direction, and as a consequence wide-spread ravages of this and other insects were checked.

To return to the picture before us, we have presumably two million trees which

were seriously damaged by insects the past season. Not a few of these were defoliated the preceding year. The probabilities indicate serious injury in 1932. This is practically certain to result in the case of the Japanese beetle and the willow-leaf beetle. The elms are very likely to suffer as they have during the past season. Is it wise to wait longer? One can not do much with a dead elm. Furthermore, many of these trees are not in a condition to stand repeated defoliations. Numerous limbs are in a weakened, sickly condition. Some may even jeopardize public safety. There is a possibility of damage claims in the case of an accident. Can tree owners afford to take these risks?

The time is approaching when it will be necessary to provide systematic protection for shade trees. The need is rapidly becoming as great as in the case of fruit trees. It would be folly to attempt to grow fruit on a commercial scale without making provision for the control of insect pests and fungous diseases. The time is coming when the need of systematic protection for shade trees will be generally recognized. It has come in the case of some localities.

It requires no great foresight, with these facts before us, to draw the conclusion that if the conditions of 1931 are allowed to continue, many thousand shade trees will succumb to natural causes within the next few years. These untoward results will undoubtedly be greatly hastened by an abundant crop of various boring insects, such as the elm borer, the elm snout beetle and the common flat-headed borer. Other trees may be expected to suffer greatly from borer attacks. Many oaks are killed each year by the two-lined chestnut borer. A deadly bark beetle is attacking and killing many hickories. These and other borers thrive in trees which have been weakened from one cause or another, and as they increase in number they attack and destroy trees which would ordinarily successfully resist invasions of this character.

There is no question as to the possibility of controlling these insects and dealing with the situation in a practical way. The principal difficulty is to secure a general realization of the value of shade trees and the fate likely to befall them unless there is protection. The communities which have suffered greatly from the work of various insect pests may well give the entire problem serious consideration. A decision should be made shortly as to whether such conditions are to be allowed to persist or whether it is advisable to face the problem and make provision for control.

A very great proportion of these trees are 50 to 100 years old. They can not be replaced in any considerable numbers in less than one or two generations. Ordinarily a magnificent elm or other tree 100 to 200 years old is much more satisfactory than a recently planted sapling. We can not escape the conclusion that a continuance of present conditions means a much more rapid loss of shade trees than can be justified. We are allowing a natural resource to be wasted. We are sacrificing esthetic as well as material values.

There is also the practical aspect to be considered. It may actually cost more to remove some of these giants than it would to provide protection, such as spraying and pruning, through a series of years. Furthermore, the cost of cutting out the dead wood in weakened trees may easily exceed the cost of spraying for two or three years, and the results are much less satisfactory. There is no getting away from these facts. There is now a choice for the owner or community concerned. There is no choice after the trees have died. The time limit may expire much sooner than many expect.

WHAT IS LEARNING?

By Dr. H. L. HOLLINGWORTH

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THE importance, for educational theory and practice, of an intelligible account of learning is clear. The persistent confusion about what learning is and how it happens is largely due to a smoke-screen thrown about the topic by the old psychology, with its jealousy of physiology. Methods of teaching, techniques of training and guidance, will continue to be hit and miss until educators realize what a simple and unmistakable process learning really is.

As a text for further discussion I shall take an account from the most recent pronouncements of one of the most esteemed writers[1] on learning. In this account the author first reviews briefly some of the attempts to explain the establishment of "connections." The "law of effect" is advocated and it is said that "One conclusion we may draw with some surety from the evidence. . . . The consequences of a connection seem to act on it directly at the time, as well as, or instead of, acting on it indirectly by causing some repetition or rehearsal or consideration of it, or by adding some motive or reason for it."

We are then asked to consider "some of the simplest cases of all learning," being assured that only the feature of "time interval" distinguishes these from "the stock experiments with animal and human learning." The case adduced is the following:

> Let a young kitten that has never had any experience with fish or meat of any kind be confronted with a row of small flakes of cooked fish, identifiable by shape, color and smell.[2] It will examine and eat one flake. Another piece is set before it, and it repeats the examination (probably abbreviated) and the eating. And so on, so long as it is hungry, with abbreviation of the examination and full retention of the eating.
>
> The same kitten confronted in the same way by a row of small friable capsules covered with meat juice but containing weak acid will examine them and may take one into the mouth. It will not repeat the act often but will soon avoid the capsule.
>
> One connection is retained, perhaps strengthened, and so acts again and again; the other is soon so weakened that it ceases to act at all. . . . In either case, the influence of the consequences seems direct.

With his usual direct touch, Thorndike has here picked a perfect example of all that is essential in learning. But in line with the current and historical predilection, he seeks for the learning in just the wrong place. Note that in neither case is any connection weakened, nor does any response cease to occur. Eating fish cakes continues to be the final response to the cakes. Avoidance continues to be the final response to the acid capsules. What precisely is it that happens in these cases, then?

The learning, as is even clearly indicated in certain unemphasized words in the quoted paragraphs, consists in an abbreviation of the examination. The "response," the terminal act, remains just what it initially was—in the first case "eating"; in the second case "avoidance." Let us look at the facts more closely.

The first kitten did not eat until after a prolonged examination. Before "eating" occurred, the first time, the kitten had to see, smell and taste the fish flake. Next time it abbreviated the examination. Upon seeing and smelling only, it bolted down the fish. Next time the

[1] E. L. Thorndike, "Human Learning," Scribners, New York, 1931.

[2] We should add "identifiable also by taste."

smelling also was dispensed with. Sight of the fish flake led to gulping it down.

The response remains unchanged. But the requisite antecedent or stimulus, called by Thorndike the "examination," is "abbreviated." There is then a reduction in the stimulus or cue necessary to instigate the unmodified response. And this cue reduction is what we mean by learning.

Consider now the second kitten. "Avoidance," we are told, was the terminal act, in the case of the acid capsules, smeared with meat juice. How was it learned, or in what did its learning consist? Initially, sight, smell and taste were all required to provoke it. Later, sight and smell sufficed. Finally, a mere glimpse of the capsules led to avoidance. Again the cue required for the terminal act is reduced. The examination is abbreviated. The response remains unchanged. And that is learning, namely, cue reduction.

Either sight, smell or taste, when the thing is "learned," suffice to provoke behavior which initially required them all. What the behavior will be depends of course on the nature of the stimuli and the native or previously acquired repertoire of the learned. In general, the terminal act may be described as one that eliminates the stimulus or irritant. Eating the fish cakes eliminates them; avoiding the capsules also eliminates them as effective stimuli.

Any case of learning ever observed can be described (and thus explained) in terms of this general tendency of living protoplasm to respond to reduced cues. It is no peculiarity of neurones, and no speculation concerning the esthetics or the social life of neurones is needed to make it intelligible.

The elementary thing about learning is a change in the stimulus, not a change in the response. As for the "connections," there is no reason to speculate about them; single neurones, so far as we now know, are individually capable of reacting to reduced cues, just as other unicellular creatures are. There is even reason to suppose that muscle cells and blood corpuscles do the same thing. And as for the statistical probabilities, they remain unchanged, and hence "connections" cannot refer to statistics. The very first time the sight of fish cakes led to eating; the sight of acid capsules led to avoidance. They did not, of course, do so *immediately*, but only with the contribution of various other joint stimuli, such as smelling and tasting. It is the elimination of the necessity for these originally requisite "contributing stimuli" that gives us the phenomenon of learning.

There is therefore just one principle that the educator needs to be in possession of, although there are of course many complex details connected with its successful administration. This single principle of education, stated in its most general terms, is—"First discover what antecedents are now required to provoke the desired consequent. Then proceed to effect a reduction in the scope of this antecedent until the expedient degree of cue reduction is achieved. The techniques of cue reduction comprise the details or subject-matter of the science of education. Education, in its most explicit form, involves just four achievements:

(a) The behavior that is desired needs first to be determined (by the teacher, the public, the philosopher, the pupil, or whomsoever is charged with this responsibility).

(b) A situation needs then to be found which will eventuate in this behavior. If it be desirable that some particular cue be made effective, this must be embedded as a detail or partial feature in this provoking situation, in such a way as not materially to modify the total response.

(c) By one or more of the various techniques this total provoking stimulus

complex must then be reduced. That is, various partial details of it, or the special details determined upon in advance, are made effective cues.

(d) If possible, sagacity must be promoted. This is simply the cooperation of cues, at least one of which functions for the general life situation or occasion, thus giving the act what we call "relevance." This is what Thorndike calls "having the neurones act with reference one to another." Whether or not this is a modifiable human trait is still doubtful, although it is clearly a variable trait within and among individuals. Capacity for it is one of the most essential mental traits.

A somewhat trivial example will serve the purpose of illustration of these four fundamental aspects of teaching. Suppose that the social philosopher, or the law, or the teacher, or a class committee should decide, at least for the moment, that boys should tip their hats to ladies. We now plan the education of such a pupil.

We discover that initially, when a woman is present, and we say to the boy "There is a lady! Now tip your hat! Watch John and do as he does! See, this is the way I do it! Go ahead now!"—thereupon he tips his headpiece.

Quite an elaborate stimulus complex, requiring (a) the presence of a woman; (b) the use of indicative and imperative language, with a long history of learning behind it; (c) concrete example by some "learned" person.

Learning has been achieved when in response to any of these cues, singly, the act results. Let us say the process is continued (simple repetition will do the trick; vividness helps; attention is also a great aid; proper distribution of practice is useful, and so on through all the rules), until the appearance of a female figure now touches off the hat-tipping.

But, after all, learning is not enough. Learning alone, without sagacity, makes neurotics. Mere learning would lead this boy to tip his hat to every magazine cover, and to half the pictures in the art gallery. It would even lead him to keep on tipping his hat repeatedly so long as the lady remained in his presence. And this would be a neurosis.

Certain other cues, from the general environment, must also be rendered effective (also of course through learning). Thus the sight of the picture frame, the feeling of having just tipped the hat, etc., would be cues leading to leaving the head-gear alone. But this effectiveness of contributing or guiding cues from the present context (as distinguished from past contexts) is what we mean by sagacity.

Learning can accomplish much. Without learning, indeed, there could be no sagacity. But there can be learning without the latter. Without sagacity, learning is as a sounding brass or a tinkling cymbal. It will function regardless of the occasion. Even if sagacity can not be taught, as perhaps it can not, any more than stature can, it may be perhaps promoted. That is, the educator can know the conditions favorable to it. The pupil can be led to discover these favorable conditions and perhaps to foster them in his own life. An emotional attitude, for example, interferes with sagacity, and emotions may perhaps be avoidable to some degree by giving thought to the matter.

Three of the educational problems, therefore, have to do directly with cue reduction (learning). And even the guiding cues involved in sagacity act on the basis of previous learning. If, then, there is a simple and intelligible account of the nature of learning, educational psychology should know it. Our contention is that this is the case—that learning is cue reduction. To understand learning does not require any inferences whatsoever about the neurones, although these also may learn.

WAS THERE A SUICIDE "WAVE" AMONG COLLEGE STUDENTS IN 1927?

By Professor ARTHUR L. BEELEY
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DURING the first three months of 1927 the American press gave unusual prominence to some twenty-six suicides by college students, mostly young men from eminent families. The public was led to believe that an epidemic of self-destruction had spread through our institutions of higher learning.

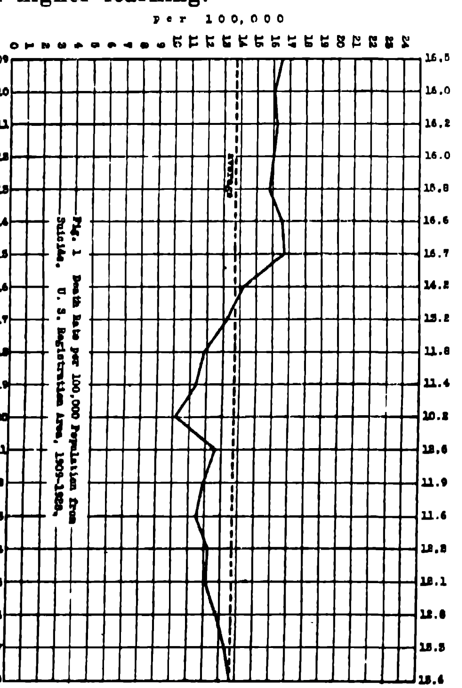

Fig. 1 Death Rate per 100,000 Population from Suicide, U. S. Registration Area, 1909–1928.

Most writers, in discussing the subject, assumed the alleged "wave" to be a fact and undertook to point out its causes and to suggest a cure. A favorite explanation made by certain glib critics of higher education was the "growing cynicism" in college circles and the "substitution of mechanistic philosophies" for the students' religious beliefs.

In the minds of many other observers, however, the question immediately arose as to whether there was a *bona fide* epidemic of suicide among college students, or whether the so-called "wave" was merely an illusion created by the newspapers' treatment of a few spectacular cases. In connection with a report of juvenile suicides in Chicago the present writer pointed out[1] that not until more data were available for the United States as a whole would it be possible to arrive at anything like a reliable conclusion in the matter.

The data necessary to answer this question satisfactorily are now available in the recently published "Mortality Statistics" of the United States Census Bureau, from which the accompanying diagrams have been prepared. Fig. 1 shows the general death rate from suicide per 100,000 population in the United States registration area from 1909 to 1928. The rate for 1927—the year of the alleged suicide "wave"—is 13.3, which, it will be seen, is 0.5 per 100,000 higher than the rate for 1926, and 0.3 per 100,000 lower than the rate for 1928. Moreover, the rate for 1927 is 0.4 per 100,000 lower than the average for the last twenty years for which data are available. It is quite obvious, therefore, that there was no marked increase in the general suicide death rate for 1927 in the United States.

A more precise answer to the question, however, can be found by considering the proportion of suicides in the age-groups from which college enrolments are generally recruited. Fig. 2 shows for each sex the percentage of suicides between fifteen and twenty-four years of age in the United States registration area from 1909 to 1928. It will be noted that the percentage of male suicides in

[1] "Juvenile Suicide," *Social Service Review*, 111: 1, March, 1929.

this age-group was 6.9 in 1927, an increase of only 0.1 per cent. over 1926. For females the percentage was 14.8 in 1927, a decrease of 1.8 over 1926. Moreover, the percentages for both sexes in 1927 are well below the average for the twenty years considered. From this comparison it is quite apparent that there was no increase in the proportion of suicides fifteen to twenty-four years of age in 1927.

It might be objected, however, that since the total number of students in American colleges and universities[2] constitutes only about six per cent. of all young men and young women fifteen to twenty-four years of age[3] in the general population, it would still be possible to have an increase in suicide among college students without such a fact being readily apparent in the totals for this entire age-group. True, but when it is remembered that the total number of all suicides in this age-group in 1927[4] was only 1,225 (742 males, 483 females), it will be seen at once that any significant increase in the number of suicides within this age-range would be readily apparent.

Looking at the matter in still another way: In 1928 there were 1,410 normal schools, colleges, universities and professional schools in the United States. If there had been an average, let us say, of one student suicide to every two such institutions (*i.e.*, a total of 705 suicides), the increase would certainly be apparent in the total number of suicides for this age-group. Even so slight an increase as one suicide to every five institutions (*i.e.*, a total of 282 suicides) would still be apparent by comparison with the preceding years.

In the last analysis, however, the question turns on the definition of the term "wave" or "epidemic." Just how much of an increase in the suicide death rate constitutes an epidemic? While a precise answer to such a question is, of course, impossible, it seems nevertheless reasonable to conclude that anything less than an average of one student suicide to every two institutions of collegiate grade can hardly be called an "epidemic" of suicide.

In conclusion it might be said, however, that while there is no evidence of a suicide "wave" among college students in 1927, the unprecedented increase in college enrolment since the war has nevertheless accentuated the number and variety of other personality problems with which college and university administrations have been forced to deal. Moreover, institutions of higher learning must inevitably pay more and more attention to the mental health of the student if they are to function effectively in preparing him (and her) to cope successfully with the psychological strains of the forties and fifties—critical life-periods during which the hazards of insanity and the neuroses, as well as suicide, are the greatest.

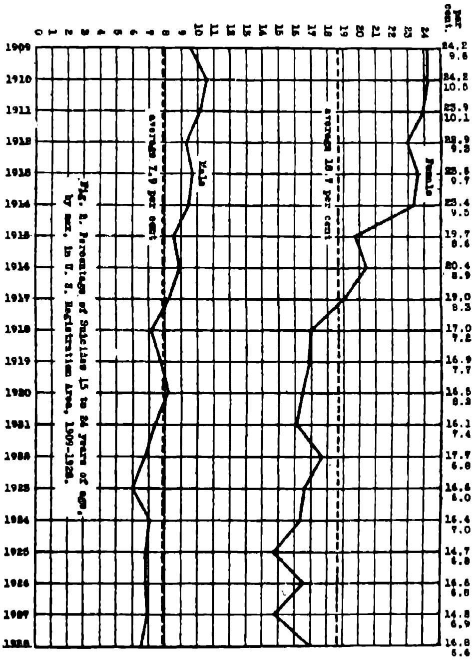

Fig. 8. Percentage of Suicides 15 to 24 years of age, by sex, in U. S. Registration Area, 1909-1928.

[2] 1,216,811 in 1928, according to the Statistical Abstract of the United States 1930.

[3] Estimated at 21,240,000 in 1927.

[4] For 1926 the total was 1,199; for 1928, 1,375. The average for the five years, 1924 to 1928, was 1,191.

THE DEVIL'S WINE

POETIC LICENSE IN AN AGE OF SCIENCE

By Dr. R. M. WINGER
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I

IF any one questions the propriety of mentioning poetry and science in the same breath, then he has only to recall other celebrated affinities to be convinced that politics has no monopoly on the production of strange bedfellows. While the law of Moses forbids the yoking together of the ox and the ass, the lion—when not engaged with the unicorn, the lamb, the lizard or the mouse—has been linked in fable or prophecy with both. Many of these traditional partnerships rest on flimsy grounds at best. A fondness for oysters, it will be recalled, was the bond of fellowship between the walrus and the carpenter. The oysters manifested a reciprocal affection of the highest order—laying down their lives for their friends. What after all is unseemly in the association of the poet and the scientist, those respective laborers in the realms of rhyme and reason?

When the humanist derides the scientist as a man who knows little Latin and less Greek, the scientist accepts the stigma complacently, since it elects him to the honorable company of Shakespeare, and places him one grade above Keats, who knew no Greek at all.

The union of poetry and science, however, is scarcely indicated by the prosy dictionary definition of science as organized knowledge or established facts. Such a definition might plausibly satisfy those benighted individuals who think that the province of science is to design pink bathtubs and develop new lacquers for automobiles, or who conceive of a flight to the poles as a scientific enterprise rather than a sporting adventure or who speak glibly of a blindfolded, scientific test by which a popular idol judges the throat-soothing qualities of a cigarette. It might also be acceptable to a newspaper editor who believes that scientific zeal is measured by the impatience with which one awaits the dawn in order to inspect the record of the nocturnal vagaries of the seismograph. Even a scientist would perhaps prefer it to the poet's definition:

> Science appears but what in truth she is
> Not as our glory and our absolute boast
> But as a succedaneum, and a prop
> To our infirmity.

At least he would wish to reserve judgment until he could get up his little Latin. But if we say with Haldane that "Science is the free activity of man's divine faculties of reason and imagination," it is at once apparent that science approaches the twilight zone of poetry, for the poet is commonly regarded as the chief custodian of the imagination.

The scientist however holds his imagination in check by an appeal to reason and experiment, for none knows better that

> 'Tis Nature you must try conclusions with.

Likewise the fancy of the architect is curbed by the stern necessity that his creations must withstand the force of gravity. But what hand shall bridle the riotous imagination of the poet, "his eye in a fine frenzy rolling"?

> Oh blithe newcomer! I have heard,
> I hear thee and rejoice.

> Oh Cuckoo! shall I call thee bird
> Or but a wandering voice?

Thus William Wordsworth in the intoxication of poetic rapture. Almost as if in answer to prayer, five years later was born a man destined to speak with some authority, although in prose, on the nature of this very phenomenon, be it bird or voice:

> . . . The instinct which leads the cuckoo to lay her eggs in other birds' nests. . . . The young cuckoo, soon after birth has the instinct, the strength and a properly shaped back for ejecting its foster brothers which then perish from cold and hunger. . . . With respect to the means by which this strange and odious instinct was acquired. . . .

Thus Charles Darwin, in a sober report of scientific observations.

Few poets have shared Wordsworth's exalted opinion of the cuckoo. Thus Shakespeare has Portia say:

> He knows me as the blind man knows the cuckoo,
> By the bad voice.

Spenser found the bird appropriate for a disparaging simile:

> So does the Cuckow, when the Mavis sings,
> Begin his witlesse note apace to clatter.

"The Cukkow and the Nightingale," a poem once attributed to Chaucer, alludes to a lover's tokeninge:

> That it were good to hear the nightingale
> Rather than the lewde Cukkow singe.

If the cuckoo as far back as Chaucer's time was regarded by lovers as a bird of ill omen, it has enjoyed even less popularity with husbands ever since the day the crow lost both his white plumage and his musical voice, as related in the Canterbury Tales. Shakespeare, benedick and poet, well understood the sentiment:

> The cuckoo then on every tree
> Mocks married men; for thus sings he
> Cuckoo
> Cuckoo, cuckoo; O word of fear,
> Unpleasing to a married ear!

But for Wordsworth the cuckoo held a peculiar charm, an irresistible fascination. Not content with modernizing The Cukkow and the Nightingale and writing three poems of his own to his "darling of the spring," he indites a fourth in praise of a mechanical counterfeit which he recommends to the sleepless:

> Better provide thee with a cuckoo clock
> For service hung behind thy chamber door.

He writes another beginning,

> Yes, it was the mountain echo,
> Solitary, clear, profound
> Answering to the shouting cuckoo,

and everywhere pays glowing tribute to the haunting Voice—"that wandering voice," "the vagrant voice," "the erratic voice," "the voice of one crying amid the wilderness." The poet likes to think of himself as the voice of one crying in the wilderness, thus identifying poet, bird, and prophet. The scientist dissents somewhat from this conclusion, insisting that a poet who can not distinguish a bird from a voice is more closely related to a cuckoo than to a Messianic prophet.

II

Wordsworth is not alone among the poets in his difficulty with the birds, nor is the cuckoo the only source of his perplexity, for he addresses a linnet as a presiding spirit, a life, a presence, a brother of the dancing leaves. Poe entertains misgivings about the raven:

> Prophet said I, thing of evil,
> Prophet still if bird or devil.

Keats will have it that the nightingale is a winged dryad; while Shelley abandons all restraint in his characterization of the skylark as a blithe spirit, cloud of fire, star of heaven, poet hidden in the light of thought, a high-born maiden, a rose embowered, a glow-worm, golden. But even Shelley's perfervid fancy must yield to Wordsworth's:

I heard the skylark warbling in the sky;
And I bethought me of the playful hare. . . .

This in a poem entitled "Resolution and Independence" but which might better have been called "The precarious state of the leech industry for senile gentlemen."

Other natural objects have been almost as bewildering as the birds:

A nun demure of lowly port;
Or sprightly maiden of Love's court,
In thy simplicity the sport
Of all temptations;
A queen in crown of rubies drest;
A starveling in a scanty vest;
Are all as seems to suit thee best,
Thy appellations.

A little cyclops with one eye

. . . .

A silver shield with boss of gold,

. . . .

I see thee glittering from afar—
And then thou art a pretty star;

This is a conundrum that would baffle a Sherlock Holmes. Just as one has conjured up a picture of a beautiful woman, the vision is shattered by the intelligence that the heroine has but one eye. Then shifting to a monocle, a needle, a spyglass, a kodak,

the
eye
appertaining to
Wilkins Micawber,
"That inward eye
Which is the bliss of solitude,"

we are humiliated to see how far short we have come of a silver shield. Recalling quickly the forms of shields, the scene dissolves and there emerges a star! Defeated, we plead "What does it all mean, poet?" and the poet obligingly answers:

Bright *flower!* for by that name at last
I call thee.

And we learn that we have been reading about a common daisy, "the poet's darling" and the lover's oracle forsooth, but the husbandman's despair. No one would conceive the bard the hero of the story when he writes:

A primrose by a river's brim
A yellow primrose was to him
And it was nothing more.

Even the usually clear-sighted Browning, in poetizing upon some object of devotion which he calls a star, but whose identity we can only surmise, exclaims:

Now it stops like a bird,
Like a flower hangs, furled.

Amid all this confusion of voices, birds, flowers and stars, one lesson seems obvious if poetry is ever to be made intelligible: Poetic license should be dispensed by the State, like a motor or a marriage license. And the aspiring poet should be subjected to a sound scientific course in ornithology and other branches of natural history. Already this need has been partially anticipated. A Johns Hopkins scientist has published a treatise, illustrated with original woodcuts on "How to Tell the Birds from the Flowers." This would be an admirable primer in the proposed Poet's Scientific Series. After the young poet has mastered the rudiments and has learned with some degree of certainty to tell a bird from a flower, he should pursue an advanced course on how to tell a bird from his brothers, the dancing leaves. But a graduate course would be necessary perhaps before he is able to distinguish a bird from a vagrant voice, a winged dryad, or a glow-worm, golden.

Another poet, not quite so sure of his intuitions, finding himself out under the firmament after dusk, reacts to his environment as follows:

Twinkle twinkle little star,
How I wonder what you are!

Now a skeptical scientist, acquainted with the imaginative ways of poets, can assure the curious reader that this pro-

fessed wonder is merely a rhetorical pose, a fine poetic gesture. Suppose he were told that the star is blended hydrogen, helium, calcium, iron and other elements found in the earth, think you he would be appeased? Not he! While he only commits himself to the simile of a diamond, doubtless he has thought also of a bird in repose, a flower hung furled, an ember, a beacon, a firefly, Lucifer, a will o' the wisp, a celestial lanthorn,

> A glow-worm in a dusky nook.

But don't press him too closely. He prefers to *fancy* that the star may be made of green cheese, that it is a divinity or some blushing nymph, translated by a friendly god to shield her from the lust of Apollo, far famed for his devotion to the arts and his pursuit of the humanities! The man who really wonders about the star is the patient astronomer who, armed with his celestial weapons, the telescope, the spectroscope and the photoscope, night after night in his lonely vigils on the mountain top attacks the mystery of the star with the persistence of that legendary army of black and white mice—alternate nights and days—which gnaw continually at the roots of the tree of life.

III

> The lunatic, the lover and the poet
> Are of imagination all compact,

declared one whose reputation as a poet age can not wither nor custom stale. But when the lunatic turns lover and the lover poet, what extravagant flights of the triune imagination may we not expect? For answer we naturally turn to the sonnet, that poetic cameo in which the lover delights to depict his lady fair. Here the poetic fancy flowers as it were in tropical luxuriance. In the few lines which tradition prescribes for the sonnet, the lover-poet can notice only those features of his mistress' beauty comprehended between the golden hair and the alabaster bosom, though he makes a surprisingly complete catalogue of those—the marble brow, the starry eyes, the rosy cheeks, the cherry lips, the pearly teeth, the ivory neck, and—O lover's doom—a heart of stone. True the inventory is not so full as Whitman's:

> Head, neck, hair, ears, drop and tympan of the ears,
> Eyes, eye-fringes, iris of the eye, eyebrows and the waking or sleeping of the lids,
> Mouth, tongue, lips, teeth, roof of the mouth, jaws and the jaw hinges,
> Nose, nostrils of the nose and the partition,
> Cheeks, temples, forehead, chin, throat, back of the neck, neck-slue, etc.

But what the poet's eyes neglect, his nose supplies:

> In Catherine's breath sweet perfume dwells,

asserts Poet Leftly.

> As air perfumed with amber is her breath,

echoes Poet Greene.

> To Arabian odors give thy breathing sweet,

pleads Poet Daniel. But for a breath of such magical virtue that it can impose its essence upon a rosy wreath, we are indebted to the deposition of Ben Jonson:

> But thou thereon didst only breathe
> And sent'st it back to me;
> Since when it grows, and smells, I swear,
> Not of itself but thee!

Are these perchance those "airy nothings" to which the poet gives "A local habitation and a name"? Or is the spurned lover worshiping from afar and ascribing to his beloved's breath the incense which he burns to milady nicotine? On the contrary, the effect is only heightened on closer approach if we may credit the expert testimony of Edmund Spenser, that master sonneteer, caroling in full-throated ecstasy:

Comming to kisse her lyps, (such grace I found,)
Me seemd, I smelt a gardin of sweet flowres,
That dainty odours from them threw around,
For damzels fit to decke their lovers bowres.
Her lips did smell lyke unto Gillyflowers;
Her ruddy cheekes, lyke unto Roses red;
Her snowy browes, lyke budded Bellamoures;
Her lovely eyes, lyke Pincks but newly spred;
Her goodly bosome, lyke a Strawberry bed;
Her neck, lyke to a bounch of Cullambynes;
Her brest, lyke Lillyes, ere theyr leaves be shed;
Her nipples, lyke yong blossomed Jessemynes;
Such fragrant flowers doe give most odourous smell;
But her sweet odour did them all excell.

Any scientist is forced to admire a trained nostril of such selective prowess that, in a moment of delirious rapture, it can disentangle this harmony of perfumes and refer each several odor to its appropriate source. The poem too furnishes one of the few authentic instances of fragrant eyes in the whole realm of scientific literature.

A bundle of myrrh is my well beloved unto me . . .
My beloved is unto me as a cluster of camphire in the vineyards of Engedi,

sang an unknown poet of old Judaea in the Song of Songs. Walt Whitman can find no sweeter fat than sticks to his own bones, and with "barbaric yawp" exults

The scent of these armpits aroma finer than prayer.

If the world were peopled with lovelorn poets, what a dismal place it would be for Lifebuoy and Listerine, those valorous twin knights who rescue fair maidens from the enchantment of the foul and insidious dragon, yclept Malodore! But even in a poet's world there is a ray of hope. For if Juliet "sweetens by her breath the neighbor air," the clown *per contra* must exhale a breath contaminated, witness the report of Casca: "The rabblement hooted and clapped their chapped hands, and threw up their sweaty night-caps, and uttered such a deal of stinking breath because Caesar refused the crown that it had almost choked Caesar; for he swounded and fell down at it." The camaraderie of the highway enabled one of the Canterbury pilgrims, without having recourse to anonymous letters, to apprise the cook of the reason why his social standing had become impaired:

Hold close thy mouth, man, by my faders kin
The devil of helle sette his foot therein,
Thy cursed breath infecte wil us alle
Fy, stinking swyn, fy! evil thee befal!

Even in the sonnet symphony, we detect one discordant note:

And in some perfumes there is more delight
Than in the breath that from my mistress reeks.

We are strangely uncertain as to which most strikes our wonder—the suspicion of halitosis in the beloved, or the germs of skepticism and rational observation discovered in the lover-poet. Can it be that this man Shakespeare had more in common with the scientist than his reputed deficiencies in the classics?

IV

But the poet does not always view the world through the prism of love, which invests ugliness itself with iridescent glory. Although he rarely concerns himself with "the fairy tales of science," there are times when he becomes a moderately reliable observer of Nature:

In the spring a fuller crimson
comes upon the robin's breast
In the spring the wanton lapwing
gets himself another crest;

In the spring a livelier iris
changes on the burnished dove
In the spring a young man's fancy
lightly turns to thoughts of love.

These remarks on the phenomena of the mating season might have been torn bodily from a scientist's notebook. What physicist could improve on the lines

Like as two mirrours, by opposed reflexion,
Doe both expresse the face's first impression?

Chaucer was well versed in the scientific lore of his age. He even composed a treatise on the astrolabe, a knowledge of which rendered him independent of the cuckoo clock in matters respecting the time of day:

Foure of the clokke it was tho, as I gesse:
For eleven foot, or litel more or lesse,
My shadow was at thilke tyme, as there,
Of such feet as my lengthe parted were
In six feet equal of proporcioun.

Your average poet, however, is singularly averse to exact statements of magnitude while the scientist is a wholesale trafficker in relations of quantity no less than in those of quality. Indeed a careful perusal of the poets warrants the conclusion that precision would be as fatal to poetry as to metaphysics. Thus if a poet wished to report the results of a census of the crab population of the inland waters of the North Pacific—taken to decide an idle wager—he would not say directly, like any scientist, that the number was found to be 1.75×10^{10}. But, adjusting his laurel wreath upon his pallid temples, he would deliver himself rather as follows:

Whilom three comrades, zealous in research,
Steeped in mathesis and biology,
Engaged in inconclusive arguments
Anent the number, just and accurate
Of Cancer's teeming pincered progeny—
He of zodiacal demesnes, fourth lord:
Result—a wager, which to resolve,
Computed they with reckoning art divine
A poll of vassals domiciled upon
The far-flung beaches of Vancouver's Sea
And to each living wight the world around
Apportioned ten.

It must have been a poet who pronounced the old Hindu curse upon the perpetrator of what, to an occidental, would appear a trivial offense:

May you be headlong plunged
Into hell's profoundest depths,
Tormented to remain until
The most delicate of maidens
Might wear away the highest peak
In proud Himalaya's range—
Striking it ever so gently
With sheerest silken gauze,
Once every thousand years!

The poet's method at once frees him from the irksome task of consulting authority and places him beyond the reach of the ciphering critic. Thus when the muse inspires the poet to write

His spear—to equal which the tallest pine
Hewn on Norwegian hills to be the mast
Of some great ammiral, were but a wand,

the reader gets the impression of a sizable spear even for an embattled archangel in rebellion. But if one wishes definite dimensions, he will invoke his knowledge of the rule of three in vain. For though a proportion is suggested, all figures—save a figure of speech—are suppressed. The tree compared to the spear is like a wand—compared to what? To an ordinary spear, the tree, or a safety match-stick, hewn on Norwegian hills? Then what is the length of a wand and what the height of the tallest pine in Norway? The poet's position is impregnable.

When Portia says,

For you
I would be trebled twenty times myself;
A thousand times more fair, ten thousand times
More rich,

it might seem that for once the poet had reached the plane of mathematical exactness. But this is only illusion, for he deals in nothing but good round numbers, which incidentally serve the demands of his rhythm. In fact it is a matter of comparative indifference to the poet whether the reading shall be trebled twenty, *i.e.*, 60 times herself, or trebled twenty times, *i.e.*, 3,486,784,401 times herself. Assuming only average endowment for her, the latter figure implies a concentration of merit double the aggre-

gate for the entire population of the globe. While the context seems to point to sixty, what after all are a few billions among poets who hold that

> A mouse is miracle enough to stagger sextillions
> of infidels?

The next line involves a difficulty. We grant that wealth might be appraised and the estate of an heiress enhanced ten-thousand fold. But is it possible that one damsel be a thousand times as fair as another—or twice, or half, or a tithe as fair? Is beauty, in fine, a commodity that is susceptible of being divided into units and magnified in numerical ratio? Is she, like intelligence, under the intrepid assaults of the objective psychologists, destined to lose her traditional place among the imponderables? Will she be dragged to the laboratory to be analyzed, measured and ticketed? We shall have, God save us, medians, quartiles, percentiles. We shall become as familiar with the kalometer[1] as with kilocycles. And to match the moron grade of intelligence, we shall require a hideon rank of pulchritude.

> Behold thou art fair my love
> Behold thou art fair,

sighs the lover of the impending Age of Mensuration. "Just how fair?" drawls the unemotional voice of the esthetical engineer.

> As the lily among the thorns
> So is my beloved among the daughters,

responds the confident lover. The objectivist demands precision—"Have you her score in the Beta Bathing Beach scales?"

> O thou fairest among women!

and the lover hazards his total resources. "Useless for laboratory records," answers the metricologist. Then, glancing at his kalometric chart, he locates the lady in the 43rd percentile, whereupon the lover is advised to refrain from his rhapsodies until he has consulted a competent oculist.

[1] Greek καλός beautiful + μετρεῖν to measure.

Pope chose verse and even rhyme as the vehicle for his serious philosophical essays, he tells us, no less for its conciseness than for its effectiveness. But few scientific writers have followed his example. A fragmentary instance of an accidentally rhymed and metered statement of a mechanical fact will interest all who have remarked the sag in telephone wires:

> And so no force, however great,
> Can strain a cord, however fine,
> Into a horizontal line
> That shall be absolutely straight.

There is not a superfluous word and no one can impugn the scientific soundness of the lines, still it must be admitted that they contain more truth than poetry.

> "Notation is crystallized thought," said an
> eminent mathematician

is a fair specimen of hexameter verse which carries a profound observation touching mathematical symbolism. The "Song of the Screw," though doubtless composed in a spirit of levity, does not properly belong in a nonsense anthology, notwithstanding its selection by so astute a judge as Carolyn Wells. On the contrary, it is an accurate and far from trivial mathematical essay turned into rhyme, as a single stanza will indicate:

> The pitch of screw, if multiplied
> By angle of rotation,
> Will give the distance it must glide
> In motion of translation.
> Infinite pitch means pure translation,
> And zero pitch means pure rotation.

In his epic of astronomy, Alfred Noyes frequently carries the reader to sublime heights of poetic feeling and dramatic intensity but he celebrates rather the heroes of the science than the science itself. In spite of these examples, there

is little reason to suppose that Euclid's Elements, Newton's Principia or Einstein's Relativity would have gained either in clarity or conciseness had the authors in their exposition resorted to

> The elegancy, facility and golden cadence of
> poesy.

V

If poetry be indeed the devil's wine, the secret of the relation between poetry and science may be revealed. For much of science owes its origin to astrology, alchemy, necromancy and other black arts, which a superstitious populace believed were under the direct patronage of the devil, as the legend of Faust attests. Even to-day when "genius" suffices to characterize the art of the poet, the skill of the scientist is heralded on every hand as *wizardry*. But magician or wizard, the scientist yet claims comradeship with the poet in the holy warfare against the ancient despotism of error

> And bravely furnished all abroad to fling
> The winged shafts of truth.

Poetry has qualities analogous to mathematics, "the queen of sciences":

> On poetry and geometric truth,
> And their high privilege of lasting life,
> From all internal injury exempt,
> I mused.

The poet proclaims his devotion to the Spirit of Beauty:

> Thus let thy power, which like the truth
> Of nature on my passive youth
> Descended, to my onward life supply
> Its calm—to one who worships thee
> And every form containing thee.

But the scientist is no stranger to beauty, he

> Anointed priest at Nature's shrine
> Chanting the eternal harmonies of the world.

Indeed, according to one poet,

> Euclid alone has looked on beauty bare
> Let all who prate of beauty hold their peace
> And lay them prone upon the earth and cease
> To ponder on themselves, the while they stare
> At nothing, intricately drawn nowhere
> In shapes of shifting lineage.

The scientist does not merely

> Spend life's prime in gaining flesh
> And giving science one more asteroid

or one more decimal or one more major planet. He is indeed remolding the material world, strewing health, comfort and convenience in his wake, as the scoffers magnanimously concede. But more—to the confusion of the scoffers, who may yet remain to pray—he is also leavening the world of ideas, as the results of his research gain gradual currency. The humblest poet of to-day would repudiate the wisdom of five centuries ago:

> For in the sterres clerer than in glas
> Is wryten, God wot, who-so coude it rede
> The deth of every man, withouten drede.

The scientist holds aloft the banner of truth while the poet keeps pure the fountain springs of beauty. The poet seeks truth in a world of illusion and the scientist finds beauty in the world of reality. Both agree with Keats, if only partially, that

> Beauty is truth, truth beauty.

The poet however divines the truth for which the scientist must delve—together firm in the faith that the truth shall make men free.

> And Science and her sister Poesy
> Shall clothe in light the homes and cities of
> the free!

SCIENCE SERVICE RADIO TALKS

PRESENTED OVER THE COLUMBIA BROADCASTING SYSTEM

THE GULF STREAM

By H. A. MARMER

ASSISTANT CHIEF, DIVISION OF TIDES AND CURRENTS, U. S. COAST AND GEODETIC SURVEY

ANY long-continued spell of unusual weather along our Atlantic coast is sure to bring out statements that this is due to a shift in the Gulf Stream. A hard winter, a dry summer, a mild winter, a cold summer—no matter what the unusual weather may be—is sure to be blamed on a change in the Gulf Stream. It is therefore not to be wondered at that the springlike weather we have been enjoying this winter along the Atlantic seaboard is being charged to some vagary in the Gulf Stream. Now, what are the facts in the case? Just what do we know about the Gulf Stream? And what are its effects on the weather? It is these questions that we want to consider briefly.

The greater part of our earth is covered by the waters of the oceans, and this great mass of water has a profound influence upon the land on which man lives. To realize how great that influence is, we need merely compare the climate on our Pacific coast with that in the Rocky Mountain states in the same latitude. In fact, the meteorologist recognizes oceanic as contrasting with continental climates. But it is not merely a question whether a given region fronts on the ocean. For there are oceanic regions within the same geographic zones which differ strikingly in climatic conditions. Scandinavia and southeastern Greenland face each other across the Atlantic Ocean, along the same parallels of latitude. Contrast the populous and prosperous lands of the one with the bleak and inhospitable shores of the other! These striking differences are due to winds and ocean currents.

The waters of the sea are never at rest. Wave and tide and current keep them continually in movement. But we must note one decided difference in these movements. In responding to tides and waves the water moves rhythmically, now up and then down, now forward and then backward. But no permanent change in the location of this water is brought about by wave and tide. Ocean currents, on the other hand, transport masses of water continuously in one direction. In doing this, a permanent change in the location of the ocean water takes place. These ocean currents form a mighty system of circulation throughout the seas, carrying the water from one region to another.

The Gulf Stream is the best known and most famous current in this system of oceanic circulation. And it is indeed a stupendous thing. The main branch comes out of the Gulf of Mexico and flows through the Straits of Florida like a mighty river 40 miles wide, 2,000 feet deep and with a velocity at the surface of about four miles an hour. From these data it is easily calculated that the Gulf Stream pours into the sea, through the Straits of Florida, about one hundred billion tons of water each hour.

In these days we have become accustomed to millions and billions; but we may perhaps appreciate better this enormous volume of water which the Gulf Stream carries into the sea by comparing it with the discharge of the

Mississippi River, which drains about 40 per cent. of the area of continental United States. On the average, the Gulf Stream pours into the sea about one thousand times as much water as the Mississippi River. Even when the Mississippi is at extreme flood stage, when its waters are carrying death and destruction in their wake, the Gulf Stream discharges about four hundred times as much water. It has recently been calculated that the Gulf Stream each hour carries twenty-two times as much water into the sea as the total amount of water discharged by all the rivers of the world in a like period of time.

The water which the Gulf Stream pours so prodigally into the sea is of a transparently blue color, and at the surface it is rather warm, having a temperature of about eighty degrees on the average. Below the surface, however, the temperature decreases rapidly and near the bottom it is decidedly cold, registering between 40 and 45 degrees. On issuing out of the Straits of Florida it continues flowing due north for about 200 miles, where it turns easterly somewhat. Here it is joined by another branch of the Gulf Stream known as the Antilles Current. The combined current, still called the Gulf Stream, now flows northeasterly along the south Atlantic states and then across the ocean, bathing the shores of northwestern Europe, and finally is lost in the Arctic seas.

It has been customary to speak of the Gulf Stream as a river in the sea and to picture it on charts with very definite boundaries. Actually this is not the case, for the lateral boundaries are not so well defined, the waters of this current merging more or less gradually with the waters of the open sea. On its western side, however, this merging zone is rather narrow, so that it is separated from the coastal waters of the northeastern states by a zone of rapidly falling temperature, to which the name "cold wall" has been applied. The abrupt change in the waters separated by the cold wall is frequently very striking. On one occasion the U. S. Coast Guard cutter *Tampa* was placed directly across the cold wall. The temperature of the water was then measured. At the bow it was found to be 34 degrees, while at the stern it was 56 degrees, a difference of 22 degrees for the 240-foot length of the ship.

The Gulf Stream loses much of its velocity and temperature in its journey across the Atlantic. Nevertheless, it affects very profoundly the climate of northwestern Europe toward which it flows. How great this influence is becomes evident from the fact that the average temperature for the month of January in northern Norway is 45 degrees higher than the January temperature normal for that latitude. Hammerfest, on the north coast of Norway, in latitude 70° 40′ north—well within the Arctic circle—is an important harbor and fishing center during the winter, while the port of Riga, lying about 800 miles to the south, is obstructed by ice during the winter season.

It is to be noted, however, that the moderating effect of the Gulf Stream on the climate of northwestern Europe is not merely a question of the carrying of relatively warm water to that region. For if there were no agency to transport this warmth on to the land the effect of this warm water would be negligible. It happens, however, that nature has provided an agency for transporting this warmth to the land, this agency being the winds. In winter the winds in northwestern Europe are prevailingly from the southwest. Blowing over the warm waters which the Gulf Stream has brought into this region they carry warm air on to the coast. It is by this means that the heat

exchange takes place in winter between the Gulf Stream and the air of northwestern Europe.

And in this relationship between the Gulf Stream and the wind we find the explanation of why the effect of the Gulf Stream on the climate of the Atlantic coast of the United States is negligible. For, aside from latitude, our climate depends mostly on the direction from which the wind comes and the force with which it blows. In winter the wind along the northeastern coast of the United States is prevailingly from the northwest, that is, from the land. Hence the warm waters of the Gulf Stream, lying several hundred miles offshore, can not moderate the climate of our northeastern states. If the winter winds along our Atlantic seaboard could be made to blow from the east and southeast, there is every reason to believe that the climate of our northeastern states would be much milder. And this would result not because the Gulf Stream moved nearer the coast, but because the winds would carry on to the land the warmth of the waters of this stream.

From time to time schemes are seriously proposed for changing the course of the Gulf Stream with the view of moderating the climate along our northeastern coast. Quite apart from the question whether the proposed schemes are adequate to bring about a change in the course of this mighty current, it is clear that such schemes are absurd. For even if the Gulf Stream were brought nearer our shores, the climate would be moderated only if the winter winds were made to blow towards the land. Indeed, there are good reasons for believing that if the Gulf Stream were to shift closer to our coast, the climate of our northeastern states would become more extreme rather than moderated—colder and more stormy in winter, and hotter and more humid in summer. For with warmer air near the coast in winter, a greater flow of cold air from the northwest would result, bringing severer storms and colder weather. In summer, the winds along the coast are more or less sea breezes, bringing the cooler air from the sea to moderate the heat. With warmer air near the shore the sea breezes would become weaker and less frequent and thus give wider scope for the hot land winds.

In connection with the question whether there has been any change in the Gulf Stream, it is of advantage to consider briefly the causes that give rise to this current. Primarily, the Gulf Stream is due to the trade winds. These winds bring about a westerly flow of the waters in the equatorial regions of the Atlantic Ocean. This flow of equatorial water on striking the coast of South America is deflected. The greater part flows to the northwest into the Caribbean Sea and then into the Gulf of Mexico from which it issues as the Gulf Stream into the Straits of Florida. The course of the Gulf Stream is thus determined by the force and direction of the winds, by the direction of the coast line, and by the configuration of the ocean bottom over which it flows.

Now if the question is asked, Has the Gulf Stream changed? the oceanographer hesitates somewhat, and asks in turn: Just what do you mean by a change in the Gulf Stream? If you mean a decided and permanent change, then the answer is unquestionably No. For a permanent change in so mighty a current can arise only from a permanent change in the force or direction of the prevailing winds, or from extensive changes in the direction of the coast line or the configuration of the ocean bottom. Since no such changes in these features have been observed, it is highly improbable that any decided change in the Gulf Stream has taken place.

But if by changes in the Gulf Stream are meant temporary changes, or more

accurately, fluctuations in the velocity, temperature and location of its waters, the answer must be Yes. From the nature of the case it is obvious that heavy winds, blowing with or against the Gulf Stream, will accelerate or retard its velocity. Furthermore, heavy winds blowing across the Gulf Stream will carry its waters out of their normal channel either nearer to the coast or further away. Variations in barometric pressure likewise will bring about fluctuations in the movement of this stream. Seasonal variations of temperature in the regions through which it flows will be reflected in somewhat similar seasonal variations in the temperature of its waters. Fluctuations in the Gulf Stream will also arise as a result of fluctuations in the currents which feed it, or which, like the Labrador Current, come into conflict with it. Such fluctuations have, in fact, been observed. But these fluctuations are temporary and fleeting, being brought about by temporary changes in wind and weather.

Now it may be asked, are the fluctuations in the Gulf Stream reflected by changes in the weather? Since meteorological conditions are affected by temperature changes in the ocean, fluctuations in the Gulf Stream undoubtedly affect the weather. But the Gulf Stream is only a minor factor in the climate of the United States; and hence the effects of its fluctuations on our weather are so small as to be negligible. While the fluctuations of the Gulf Stream are only of minor importance in regard to the weather, they affect very profoundly the conditions for life in the ocean. It is as an oceanic feature that the Gulf Stream bulks large. Oceanographers are generally not given to rhetorical flourishes; yet one of them, after spending several years in investigating the Gulf Stream, described it as "the grandest and most mighty terrestrial phenomenon."

NEW DISCOVERIES IN OLD PERSIA

By C. ROSS SMITH
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THE joint expedition of the University Museum and the Pennsylvania Museum of Art, engaged during the past season in excavation work at Tepe Hissar, a site about seven miles from the city of Damghan in northwestern Persia, has made two discoveries of great archeological importance. The expedition, under the direction of Dr. Erich Schmidt, of the University Museum, first unearthed a cemetery believed to be more than four thousand years of age. Shortly after this they discovered a Persian palace of the Sasanian dynasty, dating from the fourth century of our era. It is of the cemetery that I wish to speak first. Scores of graves were opened, revealing the remains of a people who lived at Tepe Hissar in about 2000 B. C. Their racial origin is unknown, but it is possible that they may form a connecting link between the civilizations of India and Mesopotamia. I can do no better than to describe in Dr. Schmidt's own words the extraordinary sight that met the eyes of the excavators.

"It is an awe-inspiring thing," he says, "to look upon the remains of a hundred people, dead ages ago, exposed with their mortuary equipment to the sunlight in one great necropolis. Thus we found them in the main mound at Tepe Hissar. Altogether about two hundred graves of the last Tepe Hissar people have been unearthed, and one can imagine the wealth of information and

the beautiful objects derived from them. There were remains of little children, with their miniature dishes, as well as those of men and women, with cups, bowls and pitchers of the attractive gray ware of the period. Many were found with strings of beads still attached to their necks, and bracelets, anklets and finger rings of copper clinging to their bones. It is with admiration that the hand of the archeologist touches the translucent or banded alabaster vessels, and the burnished gray or black pottery, much of it without a crack or a scratch, emerging from these burials. The position of every bone and every object is accurately surveyed.

"One of the most interesting things that we found was a little girl's grave. There had been buried with her lapis lazuli beads, gold ear pendants, onyx beads and some small figurines carved in the shape of sheep and oxen. Some plain silver pins and six little silver cups completed the child's equipment for the other world. In one of the graves were found the remains of a warrior, dead almost four thousand years. Beside him were his weapons—a bident, or long two-pronged fork, a dagger, a battle axe and a helmet. A silver pitcher, covered with the purplish gray patina that is acquired with age, lay close to his head. The left hand held two gold-coated rings and a string of lapis lazuli and onyx beads. The results of our first season's work on the Tepe Hissar cemetery are of an intensely interesting and important nature. The dead of Tepe Hissar and their mortuary equipment illuminate an entirely new phase of human culture in this region of the world."

While excavation work was being continued on the cemetery the attention of Dr. Schmidt was drawn to a promising looking mound in the neighborhood. A preliminary investigation brought up some beautiful stucco ornaments in sufficient quantity to indicate the presence of an important structure. The finds warranted the concentration of all the expedition's forces on the new site and in a short time a large area was cleared. Dr. Schmidt's idea proved to be a happy one, for on the completion of the work there was revealed an admirably planned palace structure with a central colonnaded hall about a hundred feet long with a series of chambers and rooms extending diagonally on either side. It is believed that this palace of the Sasanian dynasty of Persia was occupied about 300 A. D.

The building was constructed of burnt and sun-baked brick, the latter having, of course, pretty much disappeared with time. The main hall was probably vaulted and carried parallel rows of eight columns, four on each side, each column being nearly six feet in diameter and set in from the side wall, thus providing aisles on either side approximtely six feet in width. The entrance to the palace must originally have been impressively beautiful. The portal, with its triple arched recess, was flanked by large columns, apparently with life-sized lions as guardian deities. The columns were covered to a height of six feet with richly modelled stucco ornament. The arches, door frames, friezes and cornices were equally rich. At the corners seem to have been small towers or turrets, for observation or defense.

The interior was lavishly enriched by stucco ornament of splendid quality, giving us a few patterns somewhat new in the history of Sassanian ornament. The walls were evidently covered with rich mural paintings in purplish red, blue, carmine, white and ochre. A group of fragments show a horseman at full gallop, recalling many of those found on Sasanian plates. Some of the friezes were composed of rows of plaques containing boars' heads—an animal which the Sasanians loved to hunt.

The boars' heads closely resemble those of a stucco panel recovered from the remnants of a Sasanian palace near Varamin, Persia, in 1920, and now housed in the Pennsylvania Museum of Art.

Other plaques contain portrait figures of a smiling Sasanian queen or princess wearing a triple pearl necklace, the hair being bound with a simple fillet. These plaques were framed in a rich four-lobed leaf of a Greek character, a common ornament in the West down to medieval times. Some of the plaques are marked with Sasanian symbols which have not yet been identified, but which may throw an important light on the date of the building. The ornaments of some of the vaulted arches are particularly beautiful and clearly indicate unsuspected origins of certain Islamic patterns that were common in sixteenth century Persian carpets. The exact nature of these patterns has hitherto been obscure.

Near the palace Dr. Schmidt found a pavilion with slender columns, a type of structure that has been in favor in Persian gardens for centuries. It had been thought that these garden pavilions were a Chinese importation of medieval times, but Dr. Schmidt's finds, which tally well with what we know of the Sasanian interest in gardens, would seem to give independence to Persia in this regard.

The artistic remains of the Sasanian dynasty, a period which ranged from 220 to 650 A. D., are scanty but impressive. Prior to the finds of last summer not much had been found representative of one of the Persian empire's great dynasties. A few textiles, simple but rich in color; some bronze vessels; some silver plates with figures of uncommon force and splendor and the ruins of a few mighty monuments with colossal brick vaults are the witnesses of one of Persia's greatest periods and of an artistic epoch that influenced the whole world. For its own quality and because of what it has contributed, particularly to Romanesque and Gothic architecture, more knowledge about this period has long been sought.

The recent finds of Dr. Schmidt at Damghan give us further assurance that in architectural ornament the Sasanians were capable of achievements of the highest order. It is too early as yet to assign a definite date to the palace. When they have been finally analyzed, some badly corroded coins will probably decide the question. So far, there are reasons for thinking that the palace may date from the early part of the fourth century or the late part of the third. The palace has historical as well as artistic interest. Hitherto important Sasanian structures have all been found in the south or in the west. From this it was concluded that the Sasanian culture was much less developed in the north and in the east. The recent finds show a rich sophisticated architecture much farther to the northeast than anything previously known.

While the palace, so far as it has been uncovered, does not seem to vie in size with the colossal structures of Ctesiphon and Chahar Takun, nevertheless its existence is a proof that Damghan was an important Sasanian center occupied by some one of high rank. We have every assurance that the work at Damghan will be continued next season.

THE RESEARCH WORK OF THE UNITED STATES PUBLIC HEALTH SERVICE

By R. C. WILLIAMS, B.S., M.D.

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PRESIDENT HOOVER has said: "In public health the discoveries of science have opened a new era. Many sections of our country and many groups of our citizens suffer from diseases the eradication of which are mere matters of administration and moderate expenditure. Public health service should be as fully organized and as universally incorporated in our governmental system as is public education. The returns are a thousand fold in economic benefits and infinitely more in reduction of suffering and promotion of human happiness."

It is generally admitted that one of the basic necessities of national life is proper protection of the public health. To some this is merely a dictum which they concede to be true in a vague, general way, but about which they have never thought in concrete terms, and towards which they feel no sense of personal interest or responsibility. To others of us, particularly public-health workers, the protection of the public health is so interwoven with national prosperity and happiness, is so closely correlated with continued national existence and development, is a matter of such vital concern to every citizen in the land—quite as much as the income tax or the tariff—that we feel that every one should have some idea about what the protection of the public health means, what it ought to do and what research is being conducted still further to safeguard the health of all the people.

Generally speaking, there are four agencies which are concerned with the protection of the public health. We have, first, the private citizen, who owes it both to the community and to himself to keep himself and his family in a continuous condition of good health and so to order his acts that he will not willingly endanger the life or health of others through spreading disease. This sense of personal responsibility toward the public health is one of the qualities of individual citizenship that should be fostered by every means at our command, for it is this sense of personal initiative and responsibility which is one of the basic elements of greatness of the American nation and which will make possible the development in this country of the most effective system possible of public-health protection.

The next agency is the local community, which performs, in a collective way, for the citizen those things for the protection of the public health that he can not efficiently undertake for himself; for instance, the provision of a pure water supply, the prevention of the spread of communicable disease, the prevention of the contamination of milk and other foods and similar health safeguards.

The next agency we have is the state department of health, which performs for the communities, in a collective way, health activities which the communities themselves could not or should not undertake.

Last of all is the federal government, which, through its health agencies, undertakes for the states health activities which it would be wasteful, unwise or impracticable for them to perform for themselves. We have here, then, a continuous chain of health agencies stretching all the way from the private citizen to the national government, each

in a way autonomous, yet correlated, each having its own sphere of responsibilities and activities, each contributing its share to health protection, and each supplementing but not supplanting the other.

The U. S. Public Health Service is charged by law with a variety of functions, among which may be mentioned the protection of the United States from the introduction of disease from without, the prevention of interstate spread of disease, the suppression of epidemics, cooperation with state and local health authorities in public health matters, the supervision and control of biologic products, such as sera, vaccines and antitoxins, and investigations of the diseases of man and conditions influencing their propagation and spread.

It is necessary not only to fight epidemics and diseases while they are actually present, but also to devise means of preventing them. Granted that the necessity for research exists, the question then presents itself as to whether the government should engage in research. Experience and reason both give an affirmative answer. While it is true that in the United States, as elsewhere, a large amount of research connected with the safeguarding of public health is carried on by private agencies, there are, nevertheless, compelling reasons why the government itself should be represented in this field.

A careful analysis will show that by far the greater part of the research work conducted under the auspices of private agencies is directed to the solution of problems that are almost entirely local, or problems pertaining to curative rather than preventive medicine. On the other hand, the government, being interested in the welfare of the entire population, concentrates its efforts upon problems affecting large groups and upon preventive rather than curative methods. The government also has a duty to perform in checking up on the results of outside research to determine whether or not much of this information can be recommended for general guidance and in verifying scientific information for administrative purposes. Then, too, there are certain problems which no private agency is equipped to solve. These are problems requiring observations widely distributed in a geographic sense and, also, the problems which can be solved only by the concentration of many different research activities working in cooperation and simultaneously. In addition to all of these reasons, there is, of course, the government's obligation to promote the welfare of the people, an obligation which is not shared by outside private agencies which, properly enough, have their own ends in view in many of their activities.

Many contributions to modern medicine and hygiene have been made by the research workers of the Public Health Service. Observations made by a Service officer as to the incubation period of yellow fever aided materially in the discovery of the method of transmission of that disease. Studies made by the investigators of the Service have shown that pellagra is a disease caused by improper diet, and that the prevention and the cure of the disease lie in the eating of a well-balanced diet. The identification of the American species of hookworm as the cause of a wide-spread anemia was accomplished by an officer of the Public Health Service, and has resulted in a notable diminution of the prevalence of this disease. The cause, means of transmission and prevention of tularemia, a disease endemic in certain sections of the United States, were discovered by an officer of the Public Health Service. A worker of this national health organization has shown the similarity of the organism which causes undulant fever in human beings and

contagious abortion in cattle. Undulant fever is increasingly being recognized as a cause of human illness.

An officer of the Service has developed a vaccine for the prevention of Rocky Mountain spotted fever, a highly fatal disease. Within the past few months, announcement has been made of observations by research workers of the Service which prove the flea to be a mode of spread of endemic typhus fever, a recently recognized public health problem in this country. In connection with these studies, it has also recently been found by Service officers that Rocky Mountain spotted fever, formerly thought to be confined to the Rocky Mountain region, has probably existed along the east coast of the United States for at least a score of years. Cases formerly thought to be a severe type of typhus fever have now been identified as Rocky Mountain spotted fever of the eastern type. Workers of the Public Health Service were the first to show that serum from an abortive case of infantile paralysis neutralized the virus of that disease. This indicated more clearly than had been shown before by clinical and epidemiological studies that paralysis is not a necessary part of the disease.

These contributions of the Public Health Service to the knowledge of preventive medicine have not been made without consequent loss of health and life among the army of germ-fighters. This research salient in the battle line of public health has its casualty list. Some have fallen in the attack on yellow fever; typhoid fever and Rocky Mountain spotted fever have claimed their share; and psittacosis—the most recent cause of casualty—has taken its toll; while tularemia and undulant fever have been important causes of disability among these soldiers of science who volunteer to fight, often against an unseen foe.

The studies now being conducted by the Public Health Service relating to the various problems affecting public health are numerous. They include studies on cancer, leprosy, malaria, Rocky Mountain spotted fever, pellagra, trachoma, tularemia, meningitis, infantile paralysis, heart disease, undulant fever, typhus fever, child hygiene, industrial hygiene, milk sanitation, stream pollution, morbidity, water purification, and a number of others.

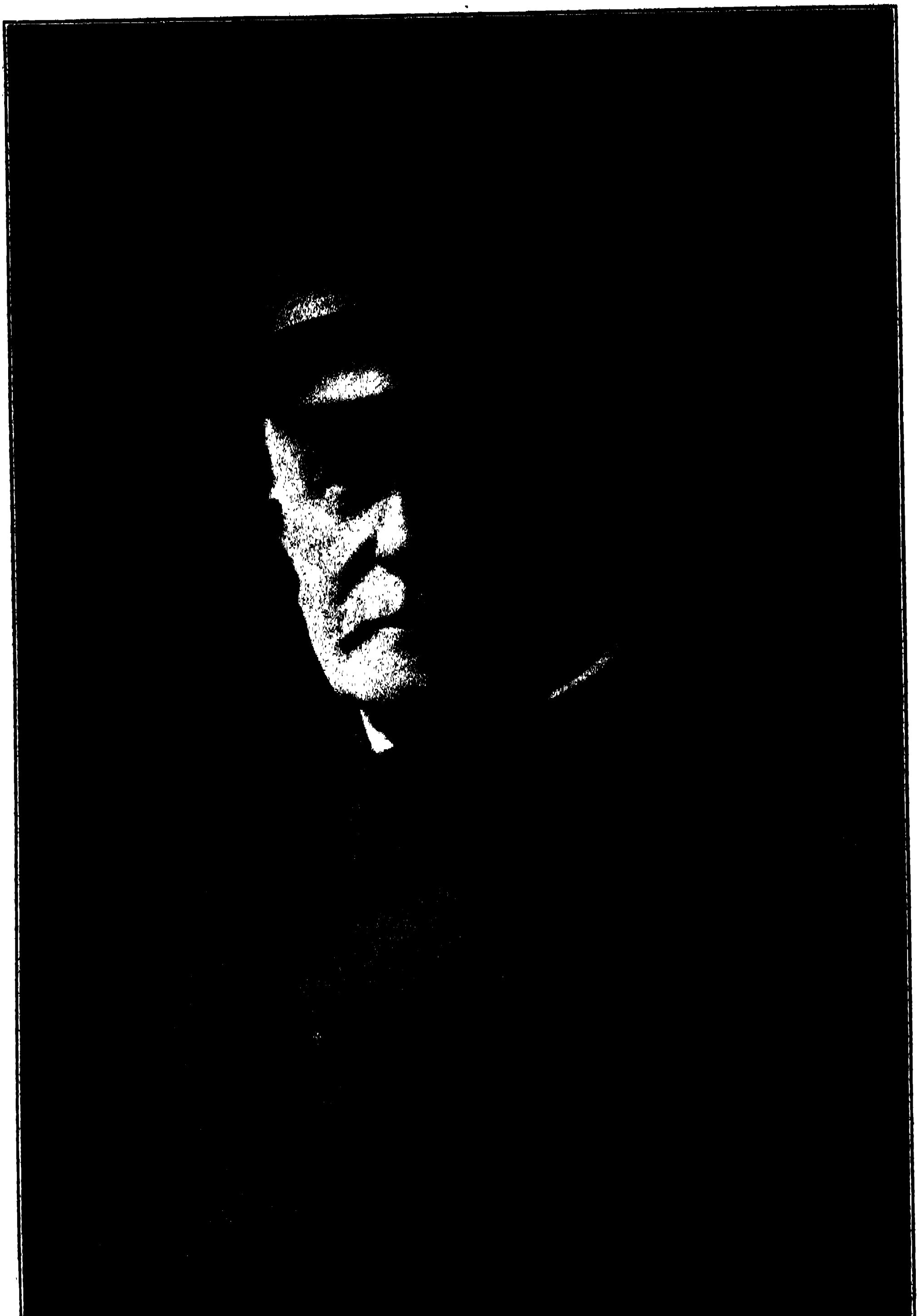
A recent act of Congress has created under the Public Health Service the National Institute of Health. In reality, the Hygienic Laboratory, which has been conducting laboratory research since 1901, has become The National Institute of Health, which, with greatly enlarged facilities, will be devoted to investigations of the underlying problems, not only of the communicable diseases, but also of degenerative diseases and environmental conditions affecting health. In the aid of research work, this act authorized the Secretary of the Treasury to accept gifts to be held in trust and to be used for the purposes mentioned, the expenditures to be safeguarded in all respects as are other governmental funds. These gifts may also be used for the establishment of fellowships.

The necessity for research work in the field of public health is fully as important to-day as it was twenty-five years ago, if not more so. With the progress of public health during the past century, there has been much improvement in conditions of general environment, such as water supplies, milk, food, housing and related matters, although there is still need for constant vigilance in the application of modern sanitary knowledge and in research involving new methods.

With the continued increase of the population in many sections, there are still many important problems relating to sewage disposal and water supplies

which must be considered. With the improvement of general environmental conditions, there is need for more emphasis upon the environment of the individual as relates to occupation, personal health, and similar matters. Although there have been many important discoveries relating to the preservation of health and the prevention of disease, there stili remain many problems to be solved. Research work in medical and public health fields is becoming increasingly difficult, and requires specialized training and intense application. The so-called degenerative diseases are among the more important causes of death. Studies in this field offer opportunities for important advances. There are problems relating to a number of the communicable diseases which are yet to be solved, among which are whooping-cough, measles, scarlet fever and meningitis. In a special group may be mentioned the virus diseases, such as infantile paralysis and influenza. Perhaps some new developments in the field of bacteriology will place within our hands the necessary weapons with which we will be able effectively to cope with these dread diseases.

One of the important needs of the present day in public health is the further development of facilities for the application of known facts relating to the prevention of disease. This means a strengthening and development of health service as rendered by local, state and federal health officials. Important scientific discoveries relating to the prevention of disease may be made, but unless such discoveries are applied, little benefit results from them. This in itself is an argument for research in methods of applying sanitary knowledge and in administration, since effective means of employing academic information are still imperfectly known. As a matter of fact, one of our investigations at the present time is a study of public health practices from the points of view of their intrinsic value and the economy and effectiveness of their application.



DR. WILLIAM WILLIAMS KEEN

THE DISTINGUISHED SURGEON OF PHILADELPHIA, SINCE 1889 PROFESSOR AND EMERITUS PROFESSOR IN THE JEFFERSON MEDICAL COLLEGE, WHO DIED ON JUNE 7, AT THE AGE OF NINETY-FIVE YEARS.

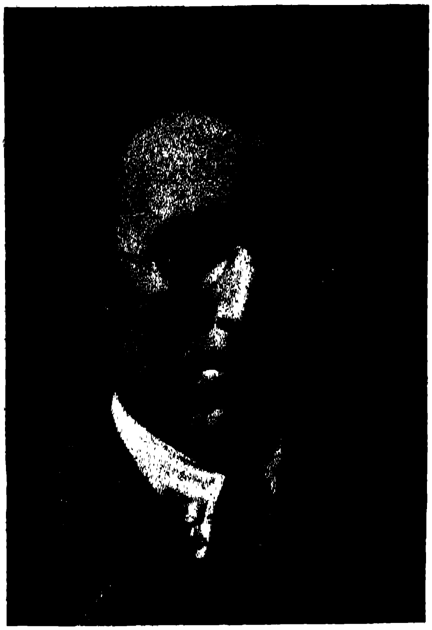
THE PROGRESS OF SCIENCE

THE ANNUAL MEETING OF THE NATIONAL ACADEMY OF SCIENCES

THE National Academy of Sciences held its annual meeting this year from April 25 to 27 in Washington. Its meetings are devoted largely to the presentation of papers of a scientific nature from different fields of science. The scientific sessions are open to the public and afford the visitor opportunity to become familiar with recent advances in certain fields of science. Thirty-five papers were presented at the annual meeting; their distribution among the sciences was as follows: astronomy, 4; chemistry, 8; physics, 6; mathematics, 1; geology, 3; engineering, 2; genetics, 4; physiology, 3, and botany, 4. Many of the papers were technical in character and not easy to follow in detail in spite of the effort which each speaker made to present his subject clearly and simply. Subjects of general interest were considered in the following papers: The cure of drug addicts, by Drs. Bancroft, Gutsell and Rutzler; Experiments on the mode of infection and means of prevention of epidemic poliomyelitis, by Dr. Simon Flexner, of the Rockefeller Institute for Medical Research; Critical geologic features in the Hoover Dam site, by Dr. C. P. Berkey, of Columbia University; Cosmic ray energies and their bearing on the photon and neutron hypotheses, by Drs. Millikan and Anderson; A deaf speaker, by Dr. F. Bedell, of Cornell University; Projection of motion pictures in relief—an experimental realization, by Dr. H. E. Ives, of the Bell Telephone Laboratories.

On Monday evening, April 25, the one hundredth anniversary of the electrical discoveries of Joseph Henry was celebrated. At this meeting Professor W. F. Magie, of Princeton University, spoke on Henry as a physicist; Mr. Bancroft Gherardi, of the Bell Telephone Company, on Henry as an electrical pioneer, and Dr. C. G. Abbot, secretary of the Smithsonian Institution, on Henry as an administrator. There was also a special exhibition of Joseph Henry's electrical apparatus, including induction coils, batteries, motor models, and the "Yale" magnet loaned by the Smithsonian Institution; a replica of the Henry electrical engine and his magnet for ringing a bell, loaned by the Albany Institute, through the Bell Telephone Laboratories; these pieces were in operation in the exhibition halls during the academy meetings. Other special apparatus shown during the meetings were: The "deaf speaker" of Professor Bedell for the use of persons with defective hearing in listening to radio programs; Dr. H. E. Ives gave a demonstration of an apparatus to illustrate his paper on the projection of motion pictures in relief; Dr. Abbot demonstrated the "periodometer" for detecting and evaluating regular periodicities in long series of observations, such as the values of the constant of solar radiation.

On Tuesday afternoon the session was given over to a symposium on climatic factors. In 1930 the Secretary of the Navy requested the National Academy of Sciences to consider and to report upon the different methods of long-range weather forecasting and the scientific bases for these methods. A committee was appointed, with Dr. J. C. Merriam, chairman, to examine into the subject. The committee realized that a knowledge of the variation, with time, of the factors responsible for the fluctuations in the weather is an essential preliminary to an analysis of the problem. In the symposium on climatic cycles the possibility of a periodic or cyclic element in earth climate was discussed from different



DR. MARSTON MORSE
PROFESSOR OF MATHEMATICS AT HARVARD UNIVERSITY

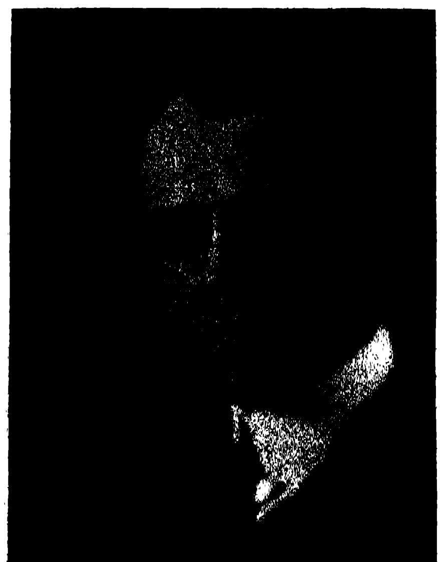
DR. JOHN C. SLATER
PROFESSOR OF PHYSICS AT THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY

DR. RAYMOND T. BIRGE
PROFESSOR OF PHYSICS AT THE UNIVERSITY OF CALIFORNIA

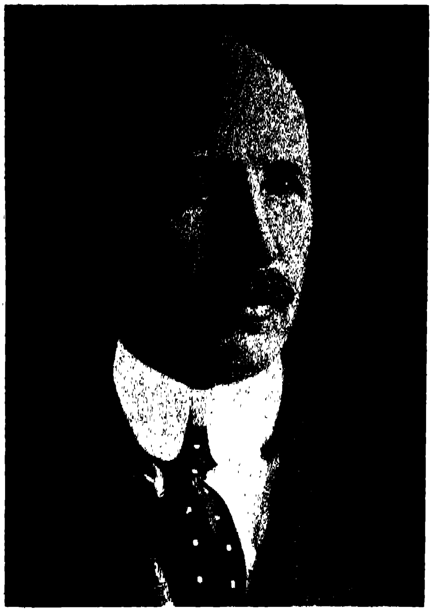
DR. F. K. RICHTMYER
PROFESSOR OF PHYSICS AT CORNELL UNIVERSITY

DR. ROBERT J. TRUMPLER
ASTRONOMER OF THE LICK OBSERVATORY

view-points. Dr. Merriam in his introductory statement emphasized the fact that "in studies of periodicity we are concerned with the factors which have to do with reception of radiation coming principally from the sun, as also with the nature of fluctuations in the source of that radiation. This symposium represents largely an attempt to present from several points of view the facts regarding radiation and its influence on the earth. The presence of periodicities or cyclic movements would not by themselves guarantee the nature of what is commonly called weather. Other factors related to varying local conditions may affect the swing of the general influences in such way as to erase their effect at least temporarily." Dr. A. E. Douglass, director of Steward Observatory at the University of Arizona, spoke on climatic cycles as illustrated in tree rings. He showed the influence of climate upon tree growth; and conversely he emphasized the significance of tree rings in registering seasonal fluctuations in climate. Dr. C. G. Abbot summarized the observations on the variations in the intensity of solar radiation and showed that changes in terrestrial temperatures are largely governed by variations in solar radiation, thus indicating that long-period forecasts of weather may be based on periodic variations in the value of the solar constant of radiation. The paper by Drs. Adams and Nicholson, of Mt. Wilson Observatory, on the nature of the solar cycle summarized the evidence on the changes in the physical aspect of the surface of the sun as a result of changes in its activity. Measured by this method, the cycle of sun-spot activity, which is most nearly periodic and of the largest amplitude, is of about 11 years' duration; but it varies between 6 and 14 years and its amplitude, by 50 per cent. of the average value. Dr. I. Bowman, of the American Geographical Society, spoke on the correlation of sedi-



DR. J. B. WHITEHEAD
DEAN OF THE SCHOOL OF ENGINEERING,
THE JOHNS HOPKINS UNIVERSITY



DR. WALTER C. MENDENHALL
DIRECTOR OF THE U. S. GEOLOGICAL SURVEY

DR. DOUGLAS JOHNSON
PROFESSOR OF PHYSIOGRAPHY AT COLUMBIA UNIVERSITY

mentary and climatic records, emphasizing the work of De Geer in Sweden and of Antevs in America on the banded clays of late glacial origin. Thus far no satisfactory correlation between these "varves" and tree rings has been made. He pointed out the need for a thorough study of the sedimentary process and its correlation with rainfall, temperature and stream discharge. From the discussion which followed the presentation of

DR. L. O. KUNKEL
PATHOLOGIST AT THE BOYCE THOMPSON INSTITUTE FOR PLANT RESEARCH

these papers it was evident that more data are needed for a satisfactory basis on which to develop adequate methods for long-range weather forecasting.

At the annual business meeting of the academy Dr. Arthur Keith, of the U. S. Geological Survey, was elected treasurer for the period July 1, 1932, to July 1, 1936. Two new members of the council were elected:

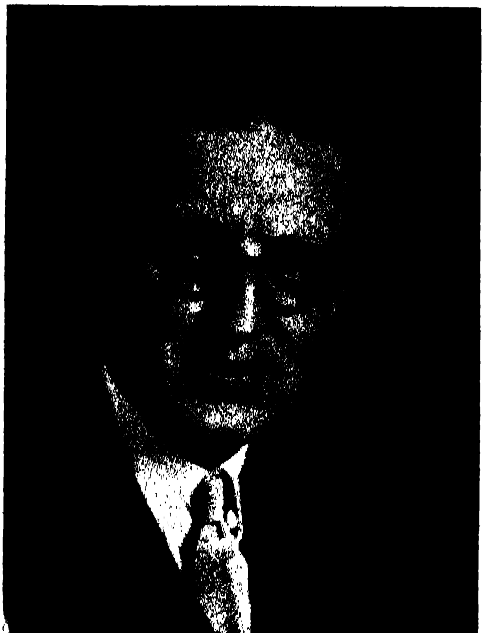
Ross G. Harrison, Yale University.
Henry Norris Russell, Princeton University.

Four foreign associates were elected:

Karl E. von Goebel, botanist, Munich, Germany.
Fritz Haber, chemist, Berlin, Germany.
Marchese Marconi, electrical engineer, Italy.
Heinrich Wieland, chemist, Munich, Germany.

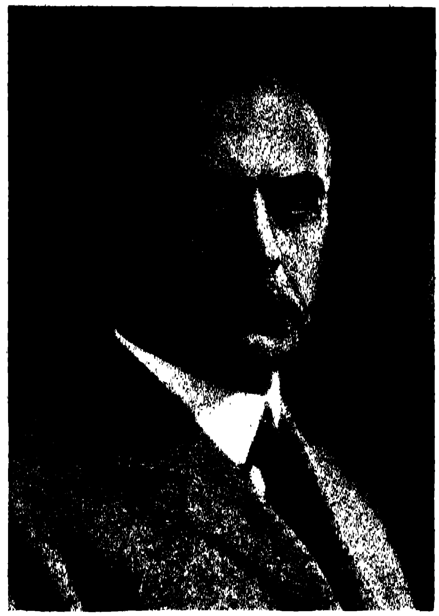
Fifteen new members were elected (the limit permitted by the rules):

Raymond T. Birge, physicist, University of California.
Edwin G. Boring, psychologist, Harvard University.
Samuel R. Detwiler, anatomist, Columbia University.



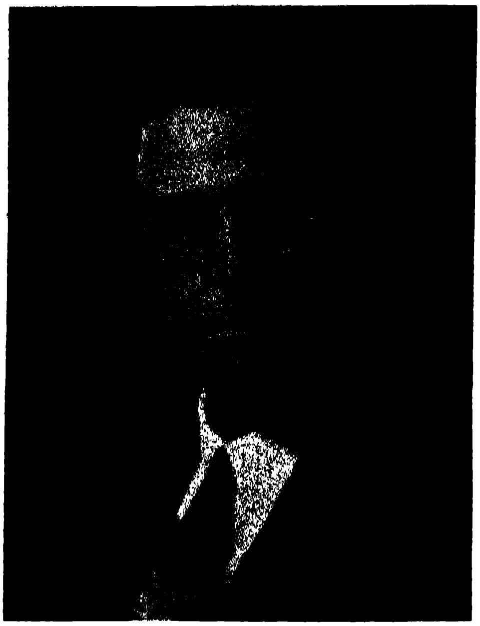
DR. S. R. DETWILER
PROFESSOR OF ANATOMY AT COLUMBIA UNIVERSITY

Walter A. Jacobs, chemotherapist, Rockefeller Institute for Medical Research.
Douglas W. Johnson, geologist, Columbia University.
Louis O. Kunkel, plant pathologist, Boyce Thompson Institute, Yonkers, N. Y.
Karl Landsteiner, pathologist, Rockefeller Institute for Medical Research.
Walter C. Mendenhall, geologist, U. S. Geological Survey.
(Harold) Marston Morse, mathematician, Harvard University.



DR. KARL LANDSTEINER
MEMBER OF THE ROCKEFELLER INSTITUTE

DR. WALTER A. JACOBS
MEMBER OF THE ROCKEFELLER INSTITUTE



DR. JOHN R. SWANTON

ETHNOLOGIST AT THE SMITHSONIAN INSTITUTION

Floyd K. Richtmyer, physicist, Cornell University.
John C. Slater, physicist, Massachusetts Institute of Technology.
John R. Swanton, anthropologist, Bureau of American Ethnology.
Robert J. Trumpler, astronomer, Lick Observatory.
Edward W. Washburn, chemist, Bureau of Standards.
John B. Whitehead, electrical engineer, Johns Hopkins University.

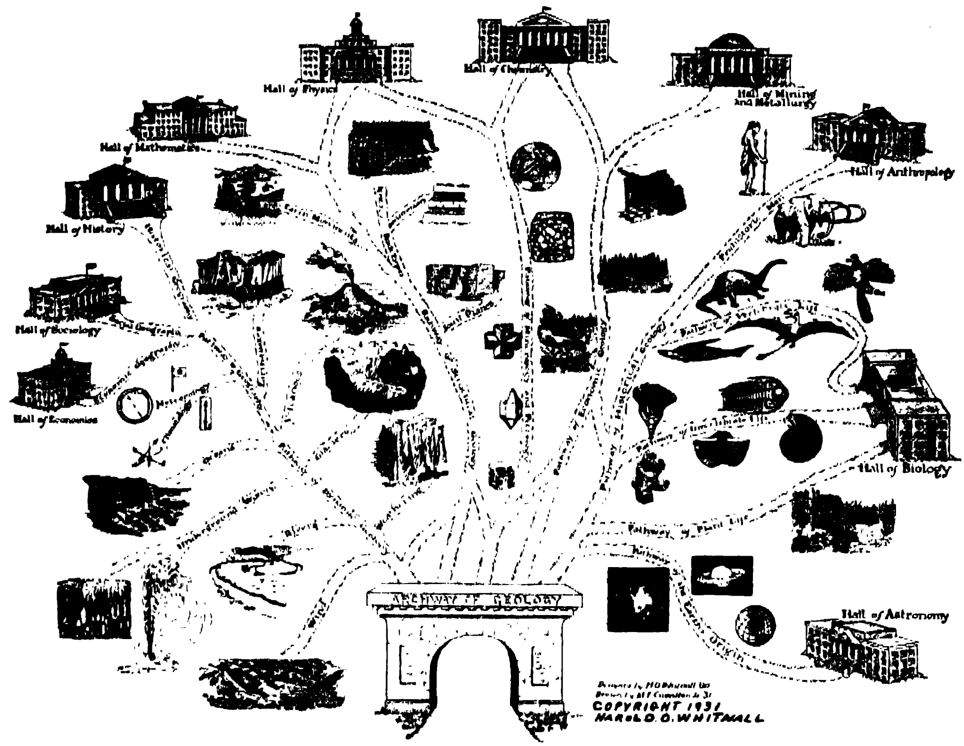
Two medals were awarded at the annual dinner on April 26: The Mary Clark Thompson Medal, with honorarium, to Dr. David White, U. S. Geological Survey, for his outstanding researches in paleontology; the presentation address was made by Professor W. B. Scott, of Princeton University. The Public Welfare Medal of the Marcellus Hartley Fund was awarded a year ago to Dr. Wickliffe Rose, at that time director of the International Health Board of the Rockefeller Foundation and president of the General Education Board. Dr. Rose died in September, 1931. The medal was received by his son, H. Wickliffe Rose. The presentation address was made by Dr. Simon Flexner, of the Rockefeller Institute for Medical Research.

The present membership of the academy is 270; the membership is limited to 300. The foreign associates number 47; the limit is fifty. Attending the annual meeting were 112 members. The average attendance at the scientific sessions was 335. The autumn meeting of the academy will be held this year from November 14 to 16, at Ann Arbor, Michigan.

F. E. WRIGHT
Home Secretary

DR. EDWIN G. BORING

PROFESSOR OF PSYCHOLOGY AT HARVARD UNIVERSITY



THE FIELD OF GEOLOGY

THE accompanying pictographic map of the Field of Geology was designed for a survey course in physical science for freshmen at Colgate University. The divergent pathways show the many ramifications of earth science and the hall of knowledge to which each pathway leads.

All the paths show cross connections. To one versed in the science of geology, these cross paths could be greatly multiplied, but to the beginner, it is sufficient to indicate that all the highways are accessible to one another. Furthermore, greater detail would show that the various halls, to which the main paths lead, could also be connected by labyrinthine passages.

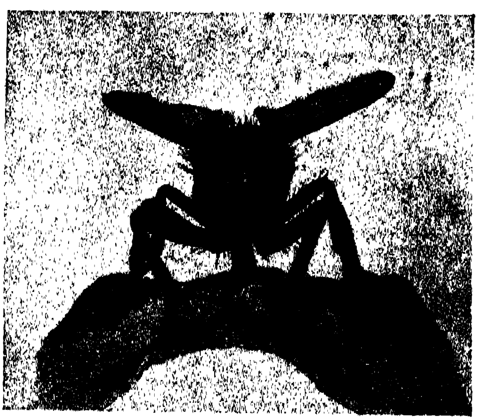
Aside from the pictorial designs which suggest the varied aspects of geological knowledge, there are mental and moral values which can not be expressed by drawing or diagram. Geology feeds the mind wherever our travels lead us, giving pleasure through the enjoyment of natural scenery, arousing the finer emotions. To philosophic minds, it supplies a vast reservoir from which may be drawn practical wisdom, fortitude and contemplation of that paradoxical thought that, although man is an insignificant organism on the mote in space which we call the earth, he is able to perceive the universe.

HAROLD O. WHITNALL
DEPARTMENT OF GEOLOGY,
COLGATE UNIVERSITY

A MECHANICAL HOUSE FLY

METHODS of visual instruction in scientific facts are constantly improving, yet we are still considerably behind the commercial world in this particular. Who has not paused in rapt attention before a shop window in which a wax figure of a man goes through the motions of adjusting his cravat or makes some other simple motions common to all of us. The business man has learned that it is a sure way of attracting the attention of the crowd. Perhaps it is the survival of a very primitive instinct that automatically arrests our attention at the sight of motion. Be that as it may, it is a fact that the eye will travel rapidly over a score or more of inanimate objects to come to rest instantly upon the slightest indication of motion among those objects.

For some time now the United States Department of Agriculture has been making its exhibits more attractive by including models of animals which have some degree of motion. The latest innovation of this kind is a huge mechanical house fly approximately four thousand times as large as an ordinary living fly. The proportions and external anatomy have been faithfully reproduced as nearly as is humanly possible. The motions of which this model is capable



are limited to the raising and lowering of the proboscis upon a pile of sugar as in the act of feeding, and a slight raising and lowering of the wings. The motions are coordinated so that immediately after the proboscis is raised from the sugar the tips of the wings rise slightly and settle back to normal position. To one watching this action the illusion is strong that the lifting of the wings denotes real satisfaction with the taste of the sugar upon the part of the automaton.

The following legend is attached to this exhibit:

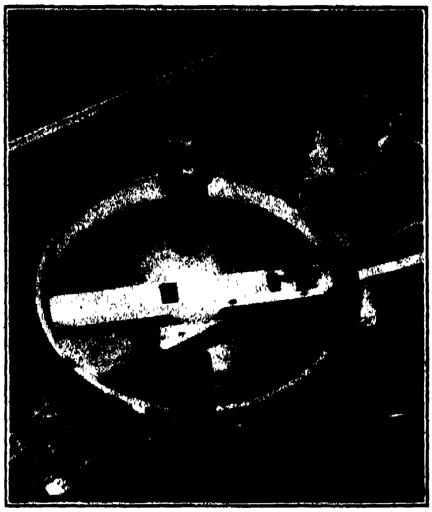
FLIES ARE DANGEROUS

The bottom of a fly's foot is soft like a cushion and there are numerous hairs on the legs. Therefore, when a fly walks over infected material of any kind thousands of bacteria become attached to the feet and legs. When the fly goes from this infected or disease-laden material to your dining table the bacteria (germs) may very readily be rubbed off in the sugar bowl, butter dish, or your child's glass of milk.

The lesson the legend conveys becomes a very forceful one when the spectator studies this huge hairy object and imagines it tracking about and nosing into the food upon the dining table. The mechanical fly is sent out by the Department of Agriculture on state fair circuits and attracts a great deal of attention wherever it is exhibited.

J. L. WEBB

A CENTRIFUGE-MICROSCOPE



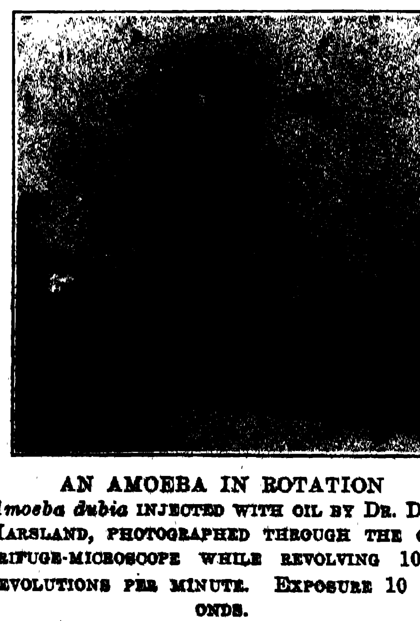
THE NEW CENTRIFUGE-MICROSCOPE
THIS DEVICE PERMITS THE OBSERVATION OF THE CHANGES TAKING PLACE WITHIN CELLS AS THEY ARE SUBJECTED TO A CENTRIFUGAL FORCE. THE CELL IS PLACED AT ONE END OF THE HOLLOW BAR AND IS WHIRLED ABOUT ON THE TURNTABLE. BY MEANS OF A SERIES OF LENSES AND MIRRORS WITHIN THE BAR THE IMAGE OF THE CELL IS CARRIED TO THE CENTER OF THE BAR SO THAT IT IS WITHIN THE RANGE OF THE SUSPENDED EYE-PIECE. THE SMALL MERCURY LIGHT, SEEN ABOVE THE END OF THE BAR, FLASHES ON THE REVOLVING CELL AS IT PASSES BENEATH, CREATING A SERIES OF IMAGES WHICH AFFORD THE OBSERVER A CONTINUOUS AND STEADY PICTURE OF THE CELL. THE PRINCIPLE IS SIMILAR TO THAT OF A MOTION PICTURE PROJECTOR.

AN advance in biological knowledge is expected to result from the use of a new type of microscope which has been evolved by Dr. E. Newton Harvey, of Princeton University, and Alfred L. Loomis. By means of this instrument observations can be made upon the changes taking place within cells as they are subjected to centrifugal force. Preliminary calculations already made with the help of the new microscope indicate that existing ideas of some of the properties of matter within the cells will have to be revised.

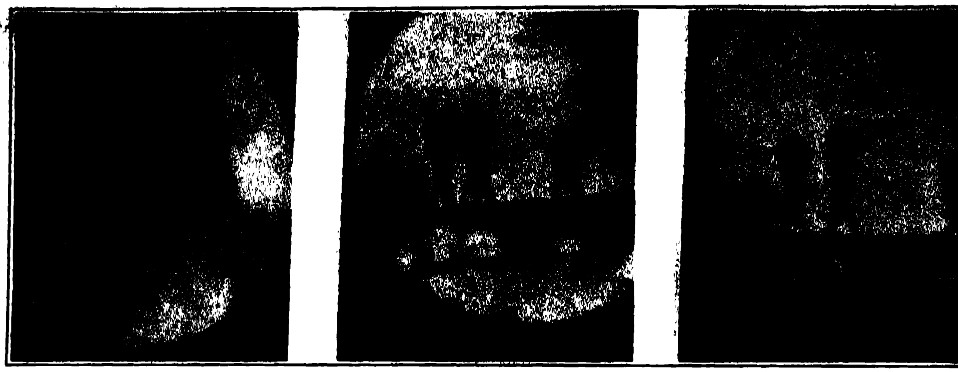
Hitherto scientists have been handicapped in their study of cells by their inability to witness and measure the various steps in the deformation of cells and in the movement of particles within them when the cells are whirled rapidly about. Knowledge of what transpires when cells are subjected to centrifugal force has been based on deductions formed by examination of the cells before and after they have been in motion.

Although the cell is being whirled about at a rate of 10,000 revolutions a minute, the new microscope presents the observer with a clear, steady picture of it throughout the process. The principle is somewhat similar to that of a motion picture projector, with the whirling cell taking the place of the film and the eye of the observer the screen. The mechanism transmits to the eye a series of images with such regularity and rapidity that they blend into a steady, continuous picture.

In the new centrifuge-microscope a disc or turntable similar in size and operation to that in a phonograph is rotated at high speed by an electric motor. Mounted on the disc and extend-



AN AMOEBA IN ROTATION
Amoeba dubia INJECTED WITH OIL BY DR. D. A. MARSLAND, PHOTOGRAPHED THROUGH THE CENTRIFUGE-MICROSCOPE WHILE REVOLVING 10,000 REVOLUTIONS PER MINUTE. EXPOSURE 10 SECONDS.



PARAMECIUM AT REST AND IN ROTATION

PARAMECIUM FILLED WITH FAT GLOBULES PHOTOGRAPHED WITH CENTRIFUGE AT REST (LEFT) AND WHILE REVOLVING 10,000 REVOLUTIONS PER MINUTE FOR ONE MINUTE (CENTER) AND FOR FIVE MINUTES (RIGHT). NOTE THE BLACK MASS OF OIL ABOUT TO PULL OFF UNDER CENTRIFUGAL FORCE.

ing along its diameter is a hollow aluminum bar one half inch thick. In this narrow bar has been built the lower lens system of a microscope. This is contained beneath an aperture at one end of the bar and is near, consequently, the outer edge of the disc. Above this aperture is placed the slide holding the cell which is to be observed. By a proper arrangement of mirrors, the image is carried to the center of the bar and is reflected upward through a second aperture to the upper lenses and the eyepiece of the microscope. This working end of the microscope is supported directly over the center of the disc and is stationary.

This arrangement provides a means of constantly observing the cell when it is in motion, but the image, if it can be seen at all at rapid speed, is nothing but a blur. The problem of obtaining a clear image was solved by the adaptation of the principle of the motion picture projector. The solution consisted in catching a glimpse of the cell for a fraction of a second during its whirl and in making possible the repetition of that glimpse at frequent and regular intervals. Thus through the projection of a series of images, a continuous picture results.

This series of images is produced by flashing a light at regular intervals above the whirling disc. The light is so regulated that its flashes coincide with the passage of the cell beneath it. The flash lasts for about one one-millionth of a second. The speed of rotation of the disc controls the frequency of the flash. Standing away from the whirling disc and looking upon it, the observer is subject to an optical illusion. The disc does not appear to be moving at all and the bar seems to be stationary beneath the light. The flash is produced by a small mercury light, the duration and intermittency of which is controlled by the discharge of electricity through the mercury vapor.

The present microscope is capable of making 10,000 revolutions a minute. Its speed is limited by the resistance of the air to the hollow aluminum bar. In a new model the bar has been stream-lined to cut down this resistance and in cross-section it will have lines not unlike those of a racing automobile.

It is expected that this model will develop speeds of from 12,000 to 14,000 revolutions a minute. A speed of 12,000 revolutions will subject the cell to a centrifugal force 17,000 times greater than gravity. This may be compared to a pull of eight and one half tons upon an object which weighs one pound.

THE SCIENTIFIC MONTHLY

AUGUST, 1932

THE TIME SCALE[1]

THE CONCEPT OF TIME

By Dr. PERCY W. BRIDGMAN

HOLLIS PROFESSOR OF PHYSICS AND NATURAL PHILOSOPHY, HARVARD UNIVERSITY

THE concept of time which I shall talk about is not the profound and sometimes poetic concept of the philosopher, but the prosaic concept of the physicist. I hope it will not be presuming too much to assume that this is also the concept of the astronomer, for I suppose that most of us will agree that the astronomer is a sort of physicist—whether a super- or a sub-physicist I shall not attempt to discuss.

As you all know the physicist has discovered recently that he must demand as essential in all concepts which can be useful to him a certain fundamental quality which I have ventured to call "operational." That is, the meaning of any concept is to be sought in the operations, whether physical or mental, which are performed in making application of the concept. This point of view received its first and perhaps most important application by Einstein in his analysis of the concept of simultaneity, and has by now become fundamental in wave mechanics as expounded by Bohr, Heisenberg, and Dirac.

Applying the operational criterion to time, the meaning of the concept of time, as it is employed by physicists and astronomers, is to be sought in the operations by which the time at which events occur is determined. The methods which we adopt for assigning a time to events change when the character of the events changes, so that time may appear in various guises. The simplest events to deal with are those taking place here and now. The time which we assign to such events may be called, following the theory of relativity, the "local time." One aspect of such local time is of such irreducible simplicity that no way has yet been found which does not treat it as unanalyzable; this of course is not a reproach because unanalyzables must always terminate any logical analysis. The aspect to which I refer is that of simultaneity—we assume that we can tell intuitively when two events in my immediate vicinity occur simultaneously. The concept of the simultaneity of two events occurring at a distance from each other is much more complicated, and it was Einstein's analysis of this which was mainly responsible for the special theory of relativity. But the simultaneity concept is not enough even for local time; in addition we must have some method of measuring local time, that is, some method of assigning numbers as the time of local events. An instrument by which such numbers are assigned is called a

[1] A symposium at the Harvard Observatory on the occasion of the dedication of the Astrophotographic Building, March 23, 1932. The new building contains the large collection of photographic plates, the library of the observatory, and many offices.

clock, but if any one should ask me for directions for constructing a clock or for specifications by which he could determine whether an instrument which purported to be a clock was actually one or not, I could not give him a satisfactory answer. In fact, here at the very root of one of our most fundamental concepts is a surprising deficiency—no satisfactory definition has yet been given of a clock. The best that we can do is to point to actual mechanical systems which we choose to call clocks, and you are of course proudly conscious that the clocks *par excellence* are afforded by the bodies of astronomy.

Distant events, of which knowledge can be obtained only by light signals, must have time assigned to them by more complicated operations than those which suffice for the local system, and this means that in our thought the time of distant events must be distinguished from the time of local events; we may distinguish by calling the time of distant events "extended" time in contrast to the "local" time of near-by events. The astronomer is obviously dealing almost entirely with extended time. It is nevertheless true, I believe, that nearly all astronomers think of the extended time of distant events in terms of the connotations of the local time of their own personal experience. For example, it is quite usual for an astronomer to speak of the "age" of a light beam, and he sometimes seems to get a particular sort of kick from the realization that the light which he receives to-day from the most distant nebula may be of the order of 100 million years old. On reflection it is obvious enough that the "old" as applied to a light beam has entirely different connotations from the "old" which may describe a hat or even a fossil at the bottom of the Grand Canyon. We have in the first place the dictum of relativity that the beam of light itself does not grow old or that if you or I could accompany the light beam on its travels we also would not notice the passage of time, but would live through the entire 100 million years with no change in any of our bodily functions, and without the need of even a single meal. What we mean when we say that the light beam is one hundred million years old is that it left the nebula one hundred million years ago, and what we mean by this again requires the most careful analysis. To give this meaning we must assign a distance to the nebula, and obtain the time by dividing the distance by the velocity of light. But to get the distance is not at all straightforward, and involves all sorts of assumptions and approximate reasonings by analogy, which leave an enormous possibility for error in the final result. It is popularly supposed that astronomy is a science of fabulous accuracy, but the accuracy is all of a special kind, namely, accuracy of angular position, whereas most distances are not at all well known, for even the most accurate may be uncertain by something of the order of one part in 10,000. It is evident, therefore, that the connotations in saying that a beam of light left a nebula one hundred million years ago are so different from the connotations involved in the time back to remote events on this earth as to make it an almost different concept.

It is also not unheard of to allow oneself to wonder what may be happening on some distant star "now." To give meaning to this question there must be some way of answering it. Even in thought the only way for me to find what is happening "now" in the distant nebula is to send a wireless message to my confederate in the nebula, who will receive it after one hundred million years, and then must consult what may be his equivalent for the library of the British Museum, where he will almost certainly find only the sketchiest sort of record of what was happening one hundred million years ago. He will then wireless the message to me, who will re-

ceive the reply at the advanced age of two hundred million years, and the reply will probably be nothing more specific than the statement that during the 10,000 years centering around the day on which I made my original inquiry a certain kind of rock was being laid down. The connotation of the "now" in distant places is obviously so different from that of ordinary experience as to make this a different concept.

We have so far assumed that there is no difficulty with the concept of remotely distant time in the local frame of reference. By this I suppose we mean that some method exists by which we can satisfactorily assign dates to local events in the remote past. There is, however, a very important limitation on the meaning that can be assigned to remote time imposed by the Heisenberg uncertainty principle. Position and velocity can not both be measured with unlimited precision, but there is a mutual restriction. If I make any sort of a determination of the position of an object, I thereby introduce an uncertainty into its velocity. But if the position of the body in past time is to be found, I must know its velocity, so that any uncertainty in its present velocity involves an uncertainty in its past position. It is obvious, I think, that the further back in time we go, the greater becomes the uncertainty in position. If we go back far enough the position becomes so blurred as to make our original object indistinguishable from others, and the past becomes radically different from the present in that the identity concept disappears. In the same way, the future becomes more and more blurred the further ahead we try to predict, until all details are lost. It is not hard to calculate that after a lapse of something like 10^{100} years the identity of any two originally distinct stars would be entirely confused, so that one must not try to peer as far as this into the future. It is not uncommon, however, to speculate about intervals of time in connection with a possible Poincaré-Zermelo cycle of the whole universe in comparison with which 10^{100} years is the mere drawing of a breath.

Not only does the astronomer deal with long intervals of time in the past in thinking about the time of dispatch of light signals which are now arriving at the earth, but he deals with enormously greater intervals of both past and future time in tracing backward or forward the course of stellar evolution in his search for the origin or ultimate destiny of the stellar universe as we know it. It is here, and in a degree characteristically peculiar to astronomy, that the greatest assumptions have to be made, and it seems to me that there is also the greatest need for perpetual vigilance and the most vivid consciousness of exactly what we are doing. Any reconstruction of the past or extrapolation into the future from observations of present configurations can be made only by assuming certain laws governing the motions. Thus we assume the conservation of linear momentum or the conservation of angular momentum, or the conservation of energy, or, if we seek for special refinement, we assume the generalized equations of relativity. But these laws themselves are generalizations from past experience, and are affected with all the uncertainty pertaining to any result of experience. To the untutored critic it must appear a trifle rash to venture to peer 10^{16} years back into the past or even greater distances into the future on the basis of laws verified by not more than 300 years' observation. The only justification for such hair-raising extrapolations is to be found in the tacit assumption of some system of metaphysics; we are convinced that nature obeys mathematically exact rules, and that we have found some of them. The reason we are convinced that we have found them is that our metaphysics persuades us that nature has a taste for the

law of the inverse square or for some other rule which our gray matter finds it comparatively easy to formulate. The metaphysical conviction that we have penetrated the arcana of nature is particularly strong in the adherents of generalized relativity, who are so convinced of the inevitableness of their philosophy that they are persuaded that even the stars in their courses must recognize the cogency of the argument. There has been no more surprising spectacle afforded by science for many a year than that of the two leading British astronomers lying down together like the lion and the lamb, giving up their most cherished and potent arguments of a few moments before, and joyfully accepting a reduction of a million fold in the time scale of the universe on the basis of a metaphysics and three not too certain checks with experiment. Surely there are plenty of unexplained phenomena to disturb so easy a complacency—the cosmic rays, which were discovered only yesterday, are becoming less well understood with every fresh investigation, the *raison d'être* of the heavy stars is at least obscure, the whole theory of stellar structure seems alarmingly chaotic to an ignorant physicist, and to-day on the front page of the papers is the "neutron," which certainly carries the potentiality of a certain amount of reconstruction.

Destructive criticism is always easy, and I am afraid that I am even more blameworthy than the ordinary destructive critic. I have nothing else to suggest, and I am sure that I would have been overcome with pride if I had had the ability to construct any one of the important modern theories. But I hope that I should not have taken what I might have done too seriously; that I would have recognized that I was merely carrying through to their logical conclusion certain consequences of formulations which I had found it convenient to make in getting into touch with the external world, and that I would have recognized, therefore, that I was to a certain extent only playing an absorbing mental game with myself. I hope that I should have been on the everlasting lookout to recognize that all my laws were probably inexact, and that I should have certainly been trying to make new experiments and better observations to get a little closer to things as they are, as I am sure all the astronomers here are doing already.

THE ASTRONOMICAL MEASUREMENT OF INTERVALS OF TIME

By Dr. ROBERT H. BAKER

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My share in these proceedings is simply to recall to those who work in other fields some features of the astronomical problem of time keeping. It is convenient for most of our purposes to suppose, with Newton, that time flows on uniformly forever, unaffected by anything else. To symbolize this concept we may imagine a body having perpetual and uniform motion in a straight line, and may keep time by measuring its progress with an appropriate yardstick. Perfectly uniform periodic motion is still more satisfactory, since this sort of motion supplies its own yardstick, the period of the oscillation.

Our problem is to contrive such an oscillator, or to find one in nature, or per-

haps several having widely different periods. It is fortunate for this purpose that so many celestial phenomena are periodic.

Axial rotation is frequent among the celestial bodies. The planets and their satellites, the stars, clusters of stars, and even the remote nebulae are known to be rotating. Mutual revolutions of associated bodies are frequent occurrences, as we see with the telescope in the case of visual double stars, or by oscillations of lines in stellar spectra, or by fluctuations in brightness as revolving stars mutually eclipse.

Eclipses of the sun and moon recur in definite cycles. Specifications of planetary orbits, such as the eccentricity of the earth's orbit or its inclination to the ecliptic, fluctuate. These are some of the periodic phenomena from which units of time of various lengths might be chosen. Often their periods are well known. Unfortunately, however, their periods are not, in general, constant.

Thus far, man has selected from the natural time units those most immediately connected with his ordinary affairs, namely, the periods of the earth's rotation, the moon's revolution, and the earth's revolution. The alternation of day and night, the cycle of the moon's phases, and the round of the seasons have drawn special attention to these periods.

The smallest of the natural time units, the day, the period of the earth's rotation, is readily established by observing the apparent rotation of the celestial scenery in the opposite direction to our movement. As the tape at which the celestial body under observation is supposed to finish its daily circuit, we select ordinarily the celestial meridian, running north and south across the sky. And to aid in timing its start and finish as accurately as possible, the transit instrument is employed; it is a small telescope mounted on a single axis in such a way that it points always along this circle of the sky.

The kind of day that is observed depends on the object chosen. If one of the stars is selected, any one which is fixed in its place relative to the others for this short duration, the day is the mechanical period of the rotation. If we select the vernal equinox, which is itself moving westward very slowly among the stars, this day, the sidereal day, is eight thousandths of a second shorter. If we select the sun, which moves eastward against the background of the stars, this day, the apparent solar day, is longer by nearly four minutes than the sidereal day.

It is not a serious matter if the length of our unit varies, so long as we know how it varies and can allow for it. The apparent solar day is conspicuously variable. But the variations are compensated for during the course of the year. The average apparent day, which is the mean solar day, is our smallest and chief time unit.

The earth's rotation is the master clock by which all terrestrial and celestial events are timed. Or what amounts to the same thing, the apparent daily rotation of the heavens is the master clock. If an hour hand is needed, we may supply it by drawing a line from the mean sun to the celestial pole in the northern sky.

It is a simple matter to read the time from this master clock. But we are disturbed by the thought that the clock may not after all be reliable. Is the earth's rotation a perfect example of perpetual, uniform motion, or is it not?

Several possibilities occur to us—several factors which may well cause our master clock to run off one way or the other. The fall of meteors upon the earth should retard the works, and those falling into the sun should produce a slipping of the hour hand, both factors conspiring to lengthen the day. Unless the supply of meteoric material is evenly distributed through space, which seems

unlikely, its contribution to the delinquency of our clock should be variable.

The Mississippi River, by transporting great quantities of material southward to regions farther removed from the center of the earth, is putting a brake on the earth's rotation. Man produces a like effect when he takes material from below the earth's surface and places it above the surface. One could calculate, I suppose, the increase in the length of the day since the erection of the Empire State Building.

The tides act as a friction brake to retard the earth's rotation. Under their influence the length of the day appears to be increasing at the rate of a thousandth of a second a century.

Suppose that one should start out with a definite impression that his watch is perfectly reliable. Presently, however, he notices that every one else is proceeding on a different schedule. He misses a train; he is late for an appointment; the town clock is fast. Eventually, he questions the reliability of his watch. In the same way, we entertain doubts as to the uniform running of our master clock, inasmuch as independent periodic phenomena, such as the revolutions of the moon and planets, depart systematically from regular schedules.

Superposed on the tidal retardation there are abrupt changes in the length of the day, as Professor Brown has clearly demonstrated, sometimes in one direction, sometimes in the other. Evidently the period of the earth's rotation is not so nearly constant as it was formerly supposed to be.

In the meantime, great improvements have been made in artificial clocks. The Shortt clock has aroused special interest because of its remarkably uniform rate. The question is raised whether the artificial timepiece may not replace the natural one as the master clock, whether it may not be used as the standard in the study of irregularities in the earth's rotation.

For the next unit, the month, the period of the moon's revolution, we must make a selection also. The mechanical period, from a star to the same star again, is the sidereal month of 27⅓ days. The month of the phases, from full moon to full moon again, is more than two days longer, more nearly in agreement with the calendar month. For the year, it is convenient for some purposes to employ the sidereal period, the interval between successive conjunctions of the sun with the same star; for other purposes we take the year of the seasons, from the vernal equinox to the equinox again, a year which is 20 minutes shorter.

But these units become inconveniently small when we turn to problems of the earth's development—the problem of the age of the earth, which Professor Holmes' researches have illuminated, and the problem of its beginning, where Chamberlin and Moulton appear for the moment to hold the field. We could use a larger unit, and we look hopefully to the earth to supply it.

Present evidence appears to show that remote objects, such as the globular clusters and the great spiral in Andromeda, are passing by in the direction of the Southern Cross. It is as though we were moving in the opposite direction, towards Cepheus in the northern sky, at the exhilarating speed of three quarters of a million miles an hour. Since this direction is at right angles to that of the great star cloud in Sagittarius, where Dr. Shapley has placed the center of the system of the Milky Way, it is supposed by many that this rapid motion of the earth is its share in the rotation of the galactic system. The period of this rotation, which is millions of years at our distance from the center, may some day be the larger yardstick for measuring the durations of cosmic processes.

THE AGE OF MAN

By Professor EARNEST A. HOOTON

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MAN is a comparatively new animal, a zoological upstart. In the parade of terrestrial life he brings up the rear. It is not strange, therefore, that anthropology, the study of man, should be the unkempt urchin of the sciences, tolerated among his elders in hope of latent promise, rather than by virtue of achievement. In this program, the consideration of man fittingly might come last, were it not for the anticlimactic effect of a descent from the spiritual remoteness of celestial bodies to the corporeal proximity of the human animal and his odoriferous primate relations.

A distinguished geologist, in one of his popular and lucid intervals, has summarized the earth's history on the face of a clock, twelve hours representing three thousand million years, by a radioactive scale of time.[2] He allots to man the last $21\frac{3}{5}$ seconds of this twelve-hour period. It is evident, therefore, that already I have enormously exceeded my due portion of this afternoon's program. Because anthropology is a shameless juvenile, pilfering from all the trees of knowledge, I have not hesitated to appropriate Dr. Chester A. Reeds' radioactive clock for anthropometric purposes. I propose to measure the time of man firstly by the duration of his culture, and secondly by the requirements of his physical evolution.

To measure man's antiquity by the age of his culture is to employ a very crude "rule of thumb." Man's culture is quite literally a "rule of thumb," since it is to the use of that mobile and opposable member that he owes most of the paraphernalia of his material civilization.

[2] Chester A. Reeds, "The Earth, Our Ever-changing Planet," pp. 1–2, The University Series, The University Society, New York, 1931.

Let us place the most important cultural achievements of man in some sort of rough chronological order. The smelting of iron ores probably began in southeastern Asia Minor not much later than 1500 B. C., roughly 3,400 years ago. Bronze was cast in the same general area at least as early as the beginning of the third millennium before Christ, more than than 4,900 years ago. Copper was reduced from its ores, hammered and cast into tools, weapons and ornaments for perhaps a thousand years before its alloy, bronze, came into use. Thus six thousand years from to-day take us back to the Stone Age, even in those areas where human culture progressed with the greatest speed.

For perhaps four millennia before the age of metals, human society in the most favored regions was already well organized upon an artificial basis of existence. Some plants were cultivated for food, and animals had been tamed and bred for the use of man. Sedentary folk were living in village communities, in huts of wattle and daub, timber, mud-brick, or possibly rough stone. The humble earthen pot already was moulded and baked by the housewife. The husband and father laboriously chipped and polished his hard stone axes, hewed timber, tended herds and flocks, while his wife stayed at home, minded the baby, and doubtless hoed the garden. The Neolithic period in Mesopotamia may have begun as early as 8000 B. C. Ten thousand years take us back to the savagery of the Old Stone Age, even, probably, in the regions where civilization was most precocious.

Just about this time we overtake the glaciers in their last retreat. According to Professor Hugo Obermaier, the vari-

ous phases of the epiglacial fluctuations occupied a period of 16,000 or 17,000 years. In the later millennia of this interval, European men were gradually emerging from cave life; Azilians in the Pyrenees were painting pebbles with symbolic signs; their cousins in South Germany were burying the heads of their dead like eggs in nests; the fine stone chipping of earlier ages had given way to a pygmy flint industry. Most of this epiglacial period, going back perhaps as far as 25000 B. C., was devoted in Europe to the development of a highly diversified industry in small stone implements and bone tools, and to the rise and decline of a realistic art, including representations of men and animals—engraving on stone and bone, and polychrome mural decorations in the caverns of southwestern Europe. The producers of this Magdalenian culture were physically modern types of men, making a living by fishing and hunting.

The Magdalenians were preceded immediately by the Solutrians, fabricators of beautifully chipped laurel leaf-shaped blades, and next by the Aurignacians, of the same fundamental European longheaded type, devoid of archaic simian attributes, skilled workers in flint and stone, gifted sculptors in the round, with a decided preference for fat ladies as artists' models. Here archeologists reach such a state of quivering timorousness that they can no longer articulate dates. The Later Stone Age or Upper Paleolithic period is thought to have begun in Europe not earlier than 27,000 or 30,000 years ago. Some parsimonious chronologists would pare the estimate to 11,000 years.

During the maximum extensions of the Würmian glaciation and probably throughout the most of the last interglacial phase a beetling-browed, prognathous, shuffling race of Neanderthal man lived in Western and Central Europe. In spite of their apelike features, they made several varieties of flaked flint implements with finely retouched edges; they buried their dead with some ceremony, and they contested successfully with the cave bear the tenancy of caverns with southern exposures. Their sway in Europe is probably to be reckoned in some hundreds of millennia. Yet they were no pioneers. Before them in Western Europe were the Acheuleans, who made symmetrical almond-shaped fist axes, which may be found by the thousands in the glacial gravels of the Somme and other rivers of Western Europe. The men who made the crude precursors of the Acheulean fist axes—pear-shaped implements with coarsely flaked sinuous edges—were the Chelleans. We know none of their skeletons, but they dropped some of their earlier and cruder tools in the Cromer Forest beds, which stand at the base of the Pleistocene. It is probable that the Old Stone Age with its easily recognizable implements made from flint nodules began as early as the inception of the glacial period.

Peering back into the shadowy Pliocene we may discern, sixteen feet down in the Red Crag, the habitation level of the Foxhall men, who used fire and chipped from flint their borers, scrapers, and knives. Anthropology owes this discovery to Mr. J. Reid Moir, of Ipswich, England. Below the Red Crag and in the drift which caps the chalk plateaus of Kent, are found the amorphous, chipped, rolled, and patinated flints, which are called Eoliths—"stones of the dawn." Many of these are undoubtedly of natural origin, but some of them were assuredly utilized by early men who had not yet succeeded in fashioning their tools into recognizable shapes.

Under these considerations I do not think that we can date the beginnings of human culture—the first construction and utilization of tools and implements—much later than the second half of the Pliocene period.

Now if we revert to Dr. Chester

Reeds' radioactive chart of geologic time, we find that he assigns one million years to the Pleistocene period and six million years to the Pliocene. The anthropologist is wholly incompetent to judge of the validity of such scales, but the present writer prefers to be a radio-activarian rather than a sedimentalist. Then, if we plagiarize Dr. Reeds' radioactive clock, we find that the twelve-hour dial of man's culture represents no less than four million years. Each second represents 92.59 years. Accordingly, if man's culture was born at mid-Pliocene noon, he began to make Chellean fist axes at 9 P. M.; at 11.54 and 36 seconds he began to draw pictures of animals and to sculp his lady friends; at 11.58 and 12 seconds he was beginning to try to tame animals and plants, to build huts and to live in communities and to polish stone tools; at a little less than 37 seconds before 12 o'clock midnight he discovered the use of iron. Of course this cultural-archeological clock is hardly accurate enough to justify the splitting of seconds.

A rather larger measure of the age of man employs the stages of human evolution, suggested by the study of recent and fossil types of man. This is a sort of foot-rule, rather than a rule of thumb, for the acquisition of a stable supporting foot seems probably to mark, better than other anatomical features, the transition from the anthropoid to the humanoid type.

The outstanding and most distinctive bodily characters of man are the stabilized supporting foot, the enlarged brain, and reduced jaws with associated chin and nasal prominences. We have to look far back beyond the stretch of 25,000 years which has elapsed since the last glacial maximum, for the genesis of any of these features. As a matter of fact, I am unable to point to any item of man's anatomy which shows definite progressive evolutionary changes since the modern types of Aurignacian men succeeded the apelike Neanderthalers in the caves of Western Europe. Great toes may have become a little greater; little toes may have become somewhat more diminutive and degenerate, palates more contracted, and teeth more liable to rot, but none of these changes are certainly consistent or cumulative, nor do they obtain in all the existing races of mankind. The wholly modern types of Aurignacian man give way to the apish Neanderthalers at the maximum of the last or Würmian Glaciation, but it is necessary to suppose that *Homo sapiens* existed in the full perfection of his present physical attributes long before that period, if not in Europe, certainly in Asia and Africa. It seems probable that the main stems of modern man—Negro, Mongoloid, and White—were differentiated from the common *Homo sapiens* stock long before the end of the Pleistocene period. I incline to the view that essentially modern types of man existed in Europe before the reign of the Neanderthalers and were responsible for the Chellean and Acheulean cultures, but discreetly withdrew from those chilly areas during the maximum of the last glaciation, leaving the archaic Neanderthalers to shiver in caves and contemplate the glacial moraines.

We have to go back to Neanderthal man to get a human type which is distinctively anthropoid in jaw protrusion and chinlessness. Even this ancient race shows considerable snout reduction, together with rudimentary chin development. No existent type of man probably has descended from the Neanderthaloid species. Neanderthal man was, phylogenetically speaking, an old maid. Furthermore, I consider him an anachronistic survival into late glacial times. The gentleman who owned the Heidelberg jaw, dug up from a depth of some 80 feet in the Mauer sands, was probably an early ancestral Neanderthaler. Some geologists place him in the first interglacial period and others in the second.

The small-brained Sinanthropus skulls, recently dug up near Peking, China, represent in teeth, jaws, and brow ridges possible precursors of the late Neanderthal types. The actual specimens recovered seem to be of Lower Pleistocene date, but the type itself must have developed long before. In Neanderthal man the brain was virtually of modern size and the foot an essentially human, supporting, non-prehensile organ. Forms probably ancestral to the Neanderthalers and assigned to Lower Pleistocene strata exhibit only slightly larger jaws, with slightly more rudimentary chins and somewhat less capacious brains.

The lady from Piltdown Common, England, *Eoanthropus Dawsoni*, burst upon us in 1912 with a virtually full-blown human brain and an almost completely chimpanzee jaw. While she may have lasted into the Lower Pleistocene, she is almost certainly the superannuated survival of a Pliocene type. She leads us to the conclusion that the human brain in some progressive stocks had attained its modern size by the beginning of the glacial epoch, although jaw reduction had scarcely begun. We do not know the Piltdown lady's feet, but we may be reasonably certain that they were not prehensile.

Pithecanthropus erectus of Java is anatomically the most archaic humanoid type. He is referred to the Lower Pleistocene of Java, but should represent the survival of an Early Pliocene or Late Miocene type. His brain was halfway down to giant anthropoid size, his jaws and teeth a little more than halfway human, his thigh bone completely that of a man. He must have walked erect on his hind legs, supported by non-prehensile feet. The human type of foot, posture, and gait may well have evolved by the end of Miocene times.

In the Middle and Upper Miocene period, we have encountered no skeletal remains of man or of humanoid types, but only generalized giant anthropoids, especially of the Dryopithecus family. According to the opinion of Professor W. K. Gregory, which I share, man was probably differentiated from a generalized and progressive Dryopithecus-like anthropoid, either in the Middle or Upper Miocene period. It is then, in our opinion, that a giant primate took to the ground, stood upon his hind legs and took the crucial step toward humanity. We must not picture him at this adolescent stage "standing with reluctant feet where the brook and river meet," but wading boldly in, not without splashing.

A little band of wilful anthropologists insists upon deriving man from some diminutive ground-dwelling Oligocene primate, apparently desiring to refer to the most remote time possible our ignominious identity with the anthropoid apes. I do not believe in this scuttling homunculus, too slow to escape by fleetness, too weak to win through by combat, and too stupid to survive by wit.

We need at least the full range of the Pleistocene and Pliocene periods to allow sufficient time for man to develop from a terrestrial erect anthropoid to his modern human status. There is no evidence for an unduly rapid evolution of human stocks. The process was multiple, involving many different lines, developing asymmetrically, at different rates of speed, and to varying degrees of removal from the anthropoidal status. Many, if not most, of these stocks became extinct. One or more have survived in modern races of man.

On the radioactive twelve-hour clock of man's physical evolution we may represent the elapsed time at seven million years, if we accept Dr. Reeds' estimate of six million years for the duration of the Pliocene period, and let man start with a supporting non-prehensile foot. Born with this essentially human member at 12 o'clock noon, he must have acquired his full brain size at about 10.17 P. M. (end of the Pliocene) and his

straight profile and jutting chin at 11.08 and 34 seconds P. M., or thereabouts (mid-Pleistocene times). It was nearly 11.59 before he began to tame wild animals, to plant, to hoe the garden, and to become domesticated.

I think that at the end of the Secondary Era, the earth was becoming tired of reptiles, irritated with their scales, and fed up with their eggs—especially, perhaps, dinosaur eggs. Then came the lively lemurs, the pop-eyed, hopping tarsiers, the amusing monkey tree-dwellers, and the mighty brachiating anthropoids. One of these last, endowed with a better brain and with a super-primate initiative, sought a richer and more abundant life upon the ground. From him, in the fulness of time, there developed man, with his stable foot, his sensitive prehensile hand, and his great receptive brain. Some men are born to sit aloft in observatories investigating the fulness of the universe. Others are born to sit on the top of flagpoles, contemplating the emptiness of their stomachs. None need be ashamed to have sprung from an ape.

THE MEASUREMENT OF GEOLOGICAL TIME

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(*Abstract*)

GEOLOGY and astronomy have common interests. Astronomy depends for its observation of great distances on a base line—the diameter of the orbit of the earth. The knowledge of this quantity is based on the size of the earth, which, in turn, rests on some small base line determined by the geodetic survey. The astronomer's light year rests on measurements of a short distance on our earth.

In the measurement of time the same is true. Measurements of great periods of time are founded on a base line of short duration. The Harvard collection of plates, which this building has been constructed to house, reached further back in time than any other. De Sitter once said: "Theories change every month, but a good observation lasts."

The geologist, like the astronomer, measures a great period of time by observations made over a very short time. A group of 50,000 observations has just been completed to determine the exact speed of the decay of radium. Helium content has been measured by Paneth and Urry in quantities as small as one hundredth of a cubic centimeter per ton, in rocks and meteorites. Such measures give us a time scale, and help both geologists and astronomers to fix events in the past and in the future from a relatively short base line.

THE AGE OF THE ROCKS

By Professor ARTHUR HOLMES
DURHAM UNIVERSITY

(*Abstract*)

THE elements uranium and thorium may be regarded as natural clocks, ticking out helium at regular intervals, and providing, in their lead content, a record of the amount of disintegration that has gone on, and hence of the age of the corresponding strata.

Determinations of lead content have led to estimates of sixty million years

for certain Tertiary rocks, and as much as 1,460 million years for some Pre-Cambrian rocks. More recently it has been found that pitchblende from Great Bear Lake has also an age of 1,460 million years, and that a specimen from Manitoba is 1,800 million years old. It is noteworthy that the three greatest recorded ages occur in North America, at points lying roughly on a north-and-south line.

From these results the lower limit of 1,800 to 2,000 million years may be given for the age of the rocks; and the earth must be at least as old as this.

The new time scale makes it possible to give the approximate lengths of successive geological periods. It also enables us to correlate past happenings on different parts of the surface of the globe, and a beginning has been made in piecing together a chronological history of the past.

In addition to estimates based on the amount of lead left from radioactive disintegration (a method inapplicable to rocks that have a high lead content of their own), the method of estimating the age of rocks by the amount of occluded helium (the remains of products of radioactive disintegration) has also wide applications. As some of the helium is bound to be lost, this method always gives lower values for the age than the method based on the lead ratio.

The helium method is applicable to basaltic rocks, and has, for instance, been applied to specimens from the geologically and historically interesting Whin Sill, in England, and to the Tertiary dykes associated with the volcano of Mull, in Scotland. The ages derived from analyses of the helium content of igneous rocks range from 28 million to 500 million years.

The work just referred to is still in its initial stages. It is hoped that the results of further researches of the same kind will lead to important knowledge in the chronology of the earth's surface, with their bearing on the age of the surface of the earth, and of the earth itself.

STABILITY OF THE SOLAR SYSTEM

By Dr. ERNEST W. BROWN
PROFESSOR OF MATHEMATICS, YALE UNIVERSITY

(*Abstract*)

At the end of the eighteenth century, the French astronomer Laplace proved that a system of planets moving around the sun in definite orbits might suffer many serious disturbances, but still would always hold together. Laplace's statement involved certain approximations which, though legitimate at the time, can now no longer be accepted. Geologists place the birth of our solar system about two thousand million years back, and the approximations of Laplace are justifiable over a period of fifty million years at the very best.

The observational problem of tracing back the paths of the planets over such enormous intervals of time is very difficult. It can be proved definitely that the present observational uncertainties in the planetary orbits are so large that the astronomer can neither predict where a planet will be two thousand million years hence, nor trace back the planet's orbit with any degree of accuracy over such an interval of time. Attempts have been made to discuss the stability by general mathematical methods, but since it is impossible to take all necessary factors into account, one can have little confidence in the result obtained from an application of these methods to our solar system.

Conclusions drawn from individual orbits of certain planets are not generally to be relied on. There are more possibilities in a statistical discussion of the orbits of the small planets moving between Mars and Jupiter (the asteroids, more than a thousand of which are now known). But on account of both the mathematical and the observational difficulties involved it is impossible to make at present any definite statement about the ultimate stability of our solar system, deduced from the law of gravitation and the present configuration.

METEORITES AND THE AGE OF THE UNIVERSE[3]

By Professor ERNST ÖPIK

UNIVERSITY OF TARTU

(*Abstract*)

FROM the relative content of helium and radium, Professor Paneth in Königsberg has determined the age of a number of meteorites; for 24 different iron meteorites he found values ranging from 100 to 2,900 million years; for the Pultusk stone meteorites, the fall of which in 1868 had been well observed, he gave a preliminary value of 500 million years, which is probably a minimum value because of possible loss of helium in space, and in our museums for over 60 years. The Pultusk meteorite was certainly of interstellar origin, and judging from preliminary results of the Arizona meteor expedition, we may expect that at least several of the iron meteorites investigated by Paneth also did not belong to the solar system. That the age of all these objects is below 3,000 million years suggests a low age also for the stellar universe. This conclusion is strongly supported by other facts mentioned below.

Statistics of the distribution of distances and relative magnitudes in wide double stars indicate that since their origin the masses of the stars can not have decreased appreciably, and that the drop in luminosity of the average star of the dwarf branch can not have exceeded half a magnitude since its origin, instead of the expected six magnitudes or more, while the most probable drop in the luminosity is zero.

The distribution of luminosities of stars in globular clusters, notably the presence of high luminosity red supergiants, as pointed out by Shapley, leads practically to the same conclusion, namely, that stars of different spectral classes can not have evolved one from another, but must have been created simultaneously, and that their age is too short for any appreciable evolution to have taken place.

Finally, the observed recession of the spiral nebulae, reflecting the phenomenon of the expanding universe, indicates a possible age for the extragalactic universe of a few thousand million years only. From all these facts we infer that probably the age of our universe does not differ very much from the age of the solar system, and that not very much more than 3,000 million years have elapsed since the spiral nebulae, the stars, and the star-dust (the meteors) were born out of the original parent system, which we call chaos because we do not know much about it.

[3] The complete paper is soon to appear in *Popular Astronomy*.

TIDES IN THE ATMOSPHERE[1]

By J. BARTELS

PROFESSOR OF METEOROLOGY, FORSTHOCHSCHULE OF EBERSWALDE, DOCENT IN GEOPHYSICS, BERLIN UNIVERSITY, RESEARCH ASSOCIATE, CARNEGIE INSTITUTION OF WASHINGTON

THE subject of this lecture is a part of the mechanics of the atmosphere, and I will therefore indicate at the outset how the atmospheric tides are fundamentally related to the main theme of these three lectures, namely, the magnetic field of the Earth and its atmosphere.

That part of the space to which we have direct access is a comparatively thin shell near the Earth's surface. A distance of 25 miles appears small to us if we travel it in horizontal direction, but a greater height than 25 miles has never been reached with any instrument. In this respect the higher regions of the Earth's atmosphere have been just as remote to us as the Moon or the Sun or the stars, and all our knowledge about them is based on the interpretation of various indirect observations. Such studies on the physics of the upper atmosphere have mainly a twofold interest: First, they reveal strong cosmic influences to which only these outermost regions are exposed, while the lower atmosphere in which we live is only indistinctly affected; and, second, the electrical state of these regions makes long-range radio communication possible.

Among the sources of information about the physical phenomena in these outermost layers, observations of terrestrial magnetism are outstanding. Nearly every variation in the Earth's magnetic force is caused by some electric phenomenon in the height, and most of the magnetic records of which Mr. Fleming showed typical examples two weeks ago are, so to say, messages from high altitudes which lend themselves to suitable interpretation. This holds for the irregular variations during magnetic storms and aurorae which Dr. Kennelly has discussed in his lecture, and particularly for the regular magnetic variations which follow the daily course of Sun and Moon. Indeed, as early as 1878, Balfour Stewart concluded from a discussion of these daily magnetic variations that they originate in the upper atmospheric layers, and that the air in these layers must conduct electricity much better than the air near the ground—a famous scientific hypothesis which was fully confirmed, over 20 years later, after the invention of wireless communication. Balfour Stewart also pointed out that the ultimate cause of the regular daily magnetic variations were atmospheric oscillations of the character of tidal motions. If, for instance, the moon would not perform, day by day, on the Earth's atmosphere that large-scale experiment that results in the lunar atmospheric tide, then we should not observe a certain kind of delicate magnetic variations and should lose, with them, a unique opportunity to study significant changes in the electrical state of the upper atmosphere. The outcome of these systematic experiments of Sun and Moon have been continually watched for many years by a number of magnetic observatories under varying conditions of season, number of sunspots, magnetic activity, distance and relative position of the Moon, and so on. The re-

[1] The third in a series of three lectures concerning the magnetic field of the Earth and its atmosphere delivered at the Carnegie Institution of Washington, March 22, 1932.

sults of the discussion have already been of great interest and will be amplified by the reduction of the data from the two magnetic observatories of this institution, which, because of their geographical locations, are specially favorable for research of this kind. While the detailed theory is fairly complicated and will not be outlined here, you will see now why the tides of the atmosphere have lately been studied more by the magneticians, who use them for the interpretation of their magnetic data, than by the meteorologists, who in fact find the tides rather tedious and of no use for explaining or forecasting the weather.

Let us now speak of the tides themselves. We think naturally at once of the regular rise and fall of the water on the seashore, twice daily, and of the corresponding tidal water-currents. These are familiar effects of the tidal forces which Moon and Sun exert on our planet. We can describe these forces as tending to stretch the Earth in the direction of the line drawn between Earth and Moon, or Earth and Sun, and while the solid Earth yields only partly to these stresses, the sea-water is fairly free to follow them. The influence of the Moon is about twice as great as that of the Sun, and since the Moon attains every day her greatest altitude in the sky about 50 minutes later than on the preceding day, the times of high water on the seacoast are about as much retarded from day to day.

Air is about a thousand times lighter than water, but it has a certain mass and is therefore subject to gravitational attraction—we can say fortunately, because otherwise the air would long ago have diffused into space, and the Earth would be as barren as the Moon whose mass is too small to hold an atmosphere. Just as the air is attracted to the Earth, it must also, like the sea-water, follow the tidal forces, because they have their

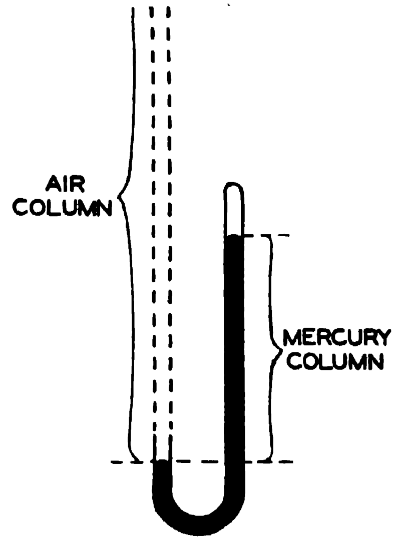

FIG. 1. BAROMETER WEIGHS ATMOSPHERE.

origin in gravitation. But how can we hope to verify this theoretical conclusion, in other words, how can we observe these tidal effects in the air? There is no coast from which we could watch the tides. One could think of detecting the atmospheric tides in the wind-changes which would be equivalent to the tidal currents in the ocean, but the wind is mostly locally distributed by varying friction since we live at the bottom of the air-ocean. At last we find in the barometer a suitable instrument. Under ordinary meteorological circumstances, namely, the weight of the mercury-column in a barometer is equal to the weight of an air-column of the same cross-section (Fig. 1). So, except during heavy storms or hurricanes, the pressure, as read on the barometer, is a measure of the mass of the air over the station; if we apply the usual barometer-corrections, we can indicate the pressure, the weight of the mercury-column, simply by the length of that column expressed in inches (about 30) or, more convenient for our purposes, in millimeters (about 760).

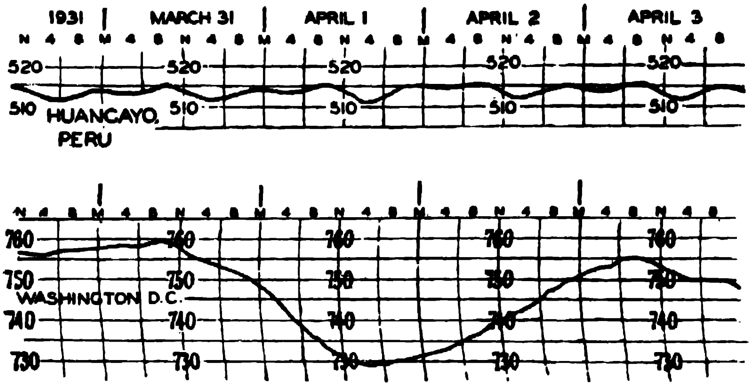

FIG. 2. BAROGRAPH CURVES AT HUANCAYO, PERU, AND WASHINGTON, D. C.

Continuous records of barometric pressure are given by the barographs, and in these curves we ought to look for tidal effects. Fig. 2 shows typical original records for the same day for two stations, one in the tropics, one in temperate latitudes. The contrast is obvious: At Washington we find the long waves connected with the weather changes during the passage of areas of high and low pressure; at first sight no systematic daily influence, no diurnal variation at all can be discerned. At Huancayo, however, we see day by day a regular double wave with the main maximum and minimum at 10 A. M. and 4 P. M., and secondary maximum and minimum at 10 P. M. and 4 A. M. (The low mean value of the pressure, 512 mm, at Huancayo is due to the altitude of our observatory, 11,000 feet above sea-level.) This regular phenomenon has been known more than 250 years and is observed everywhere in the tropics on land or sea, that is, on nearly half of the Earth's surface. The regular rise and fall of the pressure in the tropics is practically independent of the weather, only hurricanes can interrupt it. It also changes little with season, as the average diurnal curves for the months show for Key West in Florida (Fig. 3).

We are reminded of tides, because there is twice daily high pressure, and twice low pressure, but these maxima and minima occur every day at the same local time, at 10 and at 4 o'clock, and are not retarded from day to day as the ocean-tides. So they can not be related to the Moon, but must be produced by the Sun. However, they can not be simply the tides produced by the Sun, because we should then expect the maxima about noon and midnight or somewhat later, but not two hours *earlier* at 10 o'clock. Another possible cause might be the Sun's radiation, which results in the heating of the air in daytime and

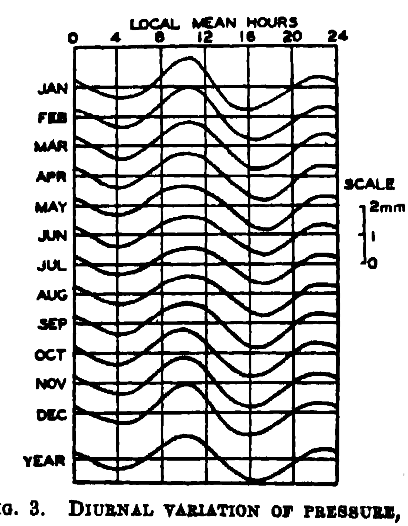

FIG. 3. DIURNAL VARIATION OF PRESSURE, KEY WEST, FLORIDA (AFTER HUMPHREYS).

the cooling at night, but this is essentially a single wave, per day, with one maximum of the temperature in the afternoon, and one minimum in the morning before sunrise, and it is hard to see how such a single wave could produce a double wave in pressure.

In order to approach this famous question, we shall analyze the barograph-records more closely and shall start with reading from these barograph-curves the values of pressure hour by hour (Fig. 4). These tabulations are, so to say, our raw material. From all the hourly values in a certain month we can form the average of all the observations taken at midnight, then those at 1 A. M., etc. In this way we derive an average variation of pressure throughout the day, the diurnal variation. These are shown in Fig. 5 for Washington, D. C., in an average for the months with the shortest days (December-January) and in an average for the months with the longest days (June–July); 14 years of observations were used. Both curves show high pressure in the forenoon, low pressure in the afternoon; the variation in the night-hours is much smaller than in the daylight-hours.

LOCAL MEAN HOURS

700mm+···

DATE	1	2	3	4	5	6	7	8	9	10	11	12	13	14
16	53.8	53.0	[illegible]	53.9	54.0	53.8	53.9	53.9	53.8	53.4	53.4	53.2	52.9	53.0
17	[illegible]	52.4	52.3	52.0	51.8	51.8	51.7	51.8	51.8	51.8	51.6	51.4	51.1	50.9
18	[illegible]	51.9	51.8	51.7	51.7	51.7	51.6	51.6	51.4	51.0	51.0	50.5	50.0	49.8
19	51.5	51.7	52.1	52.5	52.7	53.0	53.1	53.2	[illegible]	53.2	53.1	52.6	52.2	51.0
20	47.7	47.0	46.7	[illegible]	[illegible]	46.5	46.5	46.7	47.2	47.5	47.7	47.8	47.6	47.7
21	46.7	46.5	46.4	[illegible]	46.4	47.0	47.0	47.2	47.2	47.1	47.3	47.6	47.3	47.1
22	[illegible]	[illegible]	47.4	47.5	47.7	47.9	48.3	48.6	48.9	49.3	49.6	49.8	50.1	50.2
23	[illegible]	54.0	55.1	55.5	56.0	56.6	57.2	57.8	58.3	58.7	59.0	59.3	59.4	59.6
24	61.1	61.1	60.9	60.8	60.8	60.7	60.7	60.8	60.8	60.7	60.4	60.0	59.6	59.1
25	[illegible]	54.7	54.3	53.9	53.4	53.2	52.8	52.6	52.5	52.3	51.8	51.6	51.7	51.7
26	50.9	50.7	50.6	50.5	[illegible]	50.6	[illegible]	50.8	50.9	51.0	51.0	51.0	50.9	50.8
27	52.1	52.2	52.1	52.2	52.4	52.6	52.9	53.2	53.4	[illegible]	53.2	52.9	52.3	52.1
28	[illegible]	52.0	52.2	[illegible]	52.7	53.1	53.3	53.8	54.3	55.1	55.5	55.9	56.1	56.3
29	58.4	58.4	58.5	58.6	58.7	58.9	59.0	59.2	[illegible]	59.1	58.8	58.5	58.1	57.6
30	[illegible]	54.7	54.4	53.9	53.6	53.3	52.9	52.7	52.5	52.4	52.4	52.3	51.0	[illegible]
MEAN	[illegible]	53.73	53.60	53.59	53.58	53.70	53.77	53.80	53.99	[illegible]	53.97	[illegible]	53.75	53.64

FIG. 4. SPECIMEN OF HOURLY TABULATIONS OF AIR-PRESSURE, SEPTEMBER 16–30, 1930, AT POTSDAM, GERMANY.

By a simple mathematical process we can represent these diurnal curves as the sum, as the superposition, of a number of curves of very simple form, so-called sine-waves. All sine-waves have similar forms. They are mainly distin-

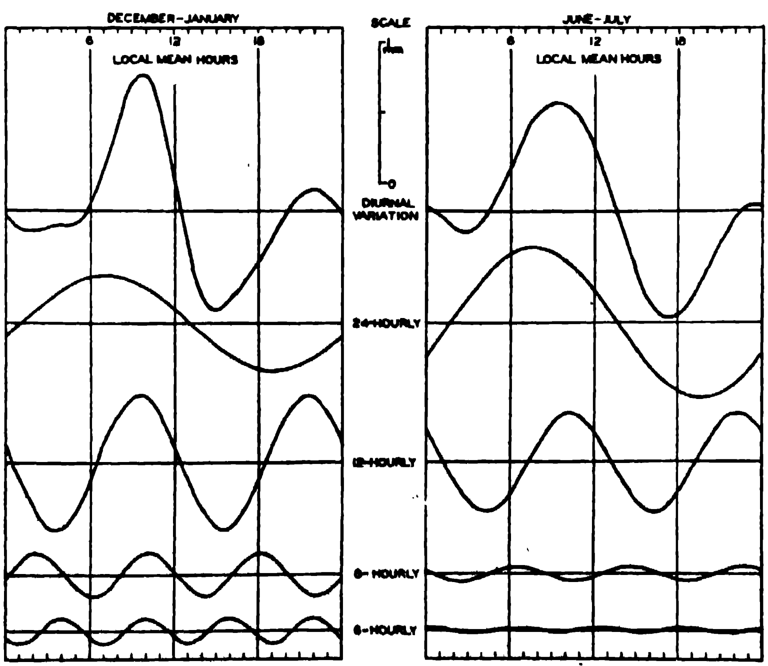

FIG. 5. HARMONIC ANALYSIS OF DIURNAL VARIATION OF PRESSURE AT WASHINGTON, D. C.

guished by their periods, that is, the times in which they complete a full wave or cycle (here 24, 12, 8 and 6 hours, respectively); and sine-waves of the same period are characterized by their amplitude, that is, their greatest deviation from the mean line, and by the time of occurrence of their maximum. The decomposition of a diurnal variation into

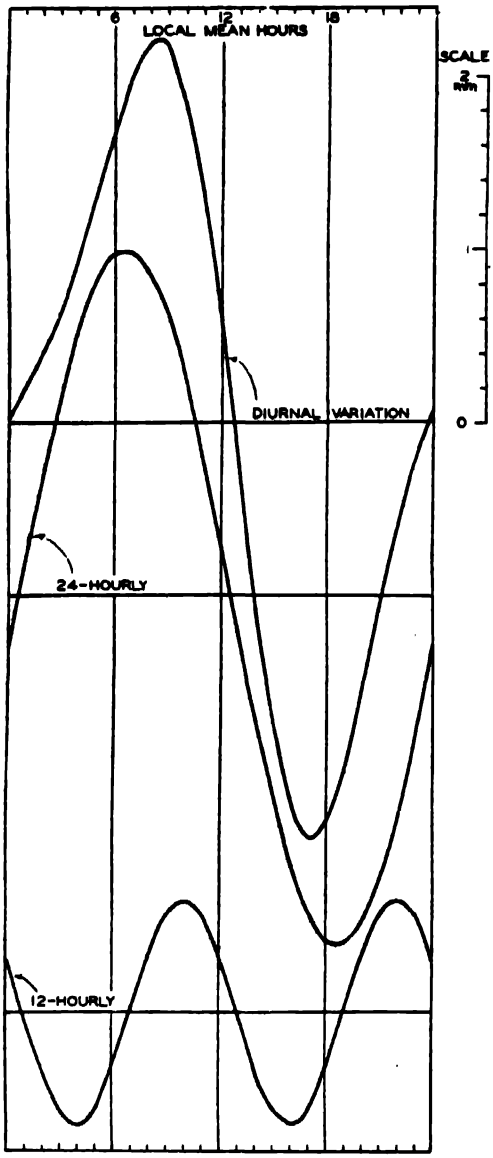

FIG. 6. HARMONIC ANALYSIS OF PRESSURE IN SUMMER, DEATH VALLEY, CALIFORNIA.

sine-waves with the periods of a full day, half a day, one third, one fourth of a day, etc., is called harmonic analysis; it would be possible to find also sine-waves of smaller periods of one fifth of a day, etc., but that is in general unnecessary, since the superposition of the first four sine-waves already approximates the diurnal variation sufficiently well.

The process of harmonic analysis is entirely formal, mathematical, and can be applied to any curve. If, for instance, we should find pleasure in counting the number of people crossing 12th Street on F Street per hour, we might also derive a diurnal variation, this curve could also be subjected to harmonic analysis, but this would be nothing but a mathematical amusement. The reason why we apply harmonic analysis to pressure observations is mainly that theory leads us to expect sine-waves in the oscillations of the atmosphere, just as sine-waves appear in every other physical phenomenon of oscillation. Such physical phenomena are abundant in number; in fact, when we listen to a radio program, our ear combines millions of different acoustic sine-waves. These are transmitted by a still greater number of electromagnetic sine-waves which pervade the space in such a multitude that we can only be glad that they do not act directly on any of our senses and turn us into nervous wrecks.

We may at once realize the advantage of harmonic analysis when we notice that the twelve-hourly sine-wave in pressure at Washington is nearly the same in winter and summer, with maxima at 10 o'clock in the morning and evening, minima at 4 o'clock in the morning and afternoon. So we have found again the tropical double wave, which is only hidden in the diurnal variation by other waves. The 24-hourly wave has larger amplitudes in summer than in winter, with the maximum about

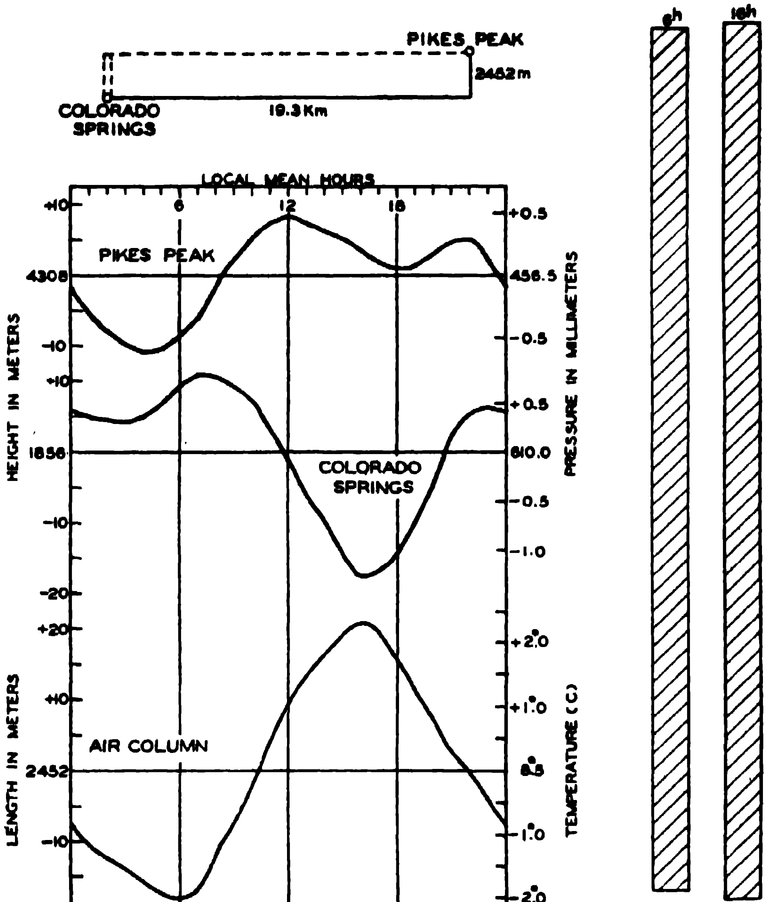

FIG. 7. TEMPERATURE-VARIATION IN THE FREE ATMOSPHERE DERIVED FROM BAROMETRIC OBSERVATIONS.

6 o'clock in the morning. The 8-hourly wave is interesting because in winter it has its first maximum about 2 o'clock, but in summer its first minimum at the same time; the crests and troughs of the 8-hourly wave have reversed their places from winter to summer.

Some examples will show the great differences in the diurnal variation of pressure at different stations. The diurnal variation is especially pronounced at the bottom of valleys; at Death Valley in California, the pressure in summer at 5 P. M. is 4.6 mm smaller than at 8 A. M. (Fig. 6). Harmonic analysis finds the 24-hourly wave responsible, while the 12-hourly wave is again quite normal as to amplitude and time of maximum.

Next we consider the summer conditions on top of a mountain (Pike's Peak) and at a base-station (Colorado Springs); the relative position of the two stations is indicated in the small vertical section at the top of Fig. 7. The diurnal variations of pressure, as shown in the two upper curves, look very different.

We can account for this difference in the following way: Consider a barometer at a fixed height. At a certain time it may indicate a pressure of 750 mm. We know that pressure increases downward and decreases upward in the

atmosphere. If, therefore, the reading of the barometer after some time rises to 751 mm, we can find vertically above the station a level where the pressure is 750 mm, and if our fixed barometer falls below 750 mm, we can find the pressure 750 mm at some lower level. In other words, every rise and fall in the reading of a barometer can be expressed as the rise or fall of the level where the pressure has a given constant value.

The two upper curves in Fig. 7 can therefore be interpreted in two ways—either using the scales on the right, as diurnal variations of pressure in the fixed heights 4,308 m and 1,856 m above sea-level, or, using the scales on the left, as the diurnal rise and fall of the levels of constant pressure 456.5 mm and 610.0 mm. These levels of constant pressure are so nearly horizontal that the data for Pike's Peak can be considered as a good approximation for the conditions in the free atmosphere over Colorado Springs. The two curves represent, therefore, the vertical movements of the upper and lower levels of a certain vertical air-column in the course of a day. Remembering that the barometer weighs the atmosphere, we see that the total mass M of air above the bottom level of the column must be constant (corresponding to the constant pressure 610.0 mm), and also the total mass m of air above the top level of the column (corresponding to the constant pressure 456.5 mm); consequently, the mass of the air $(M-m)$ in the column also must be constant. The third curve in Fig. 7, which is the difference of the two upper curves, represents therefore the changes in the length of this column throughout the day. It is, on the average, 2,452 m long, but at 6 A. M. it is 18.0 m shorter, and at 4 P. M. it is 20.7 m longer, as shown to scale in the two columns sketched in the right-hand part of the diagram. These contractions and dilatations of the column can only be interpreted as corresponding changes in the mean temperature of the air in the column because, as we have seen, the column contains always the same mass of air. This is done by the scale at the right of the lower curve; the column which, on the average, has the temperature 8.°5 C. is 2.°0 C. cooler at 6 A. M., and 2.°3 C. warmer at 4 P. M. We have thus obtained from barograph-readings an estimate for the variation of the temperature in the free air between the levels of the two stations on top and at the foot of Pike's Peak—and a very reliable estimate it is, which could not be as readily deduced from direct balloon-observations of temperature.

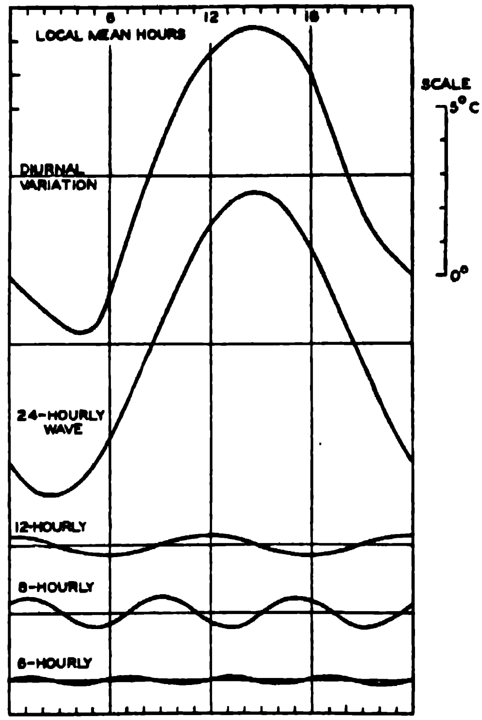

FIG. 8. HARMONIC ANALYSIS OF AIR-TEMPERATURE IN JUNE AT POTSDAM, GERMANY.

I have treated this simple calculation at some length here, because its plausible result incidentally supports our rule on which the calculation was based, namely,

that the barometer weighs the atmosphere. This has sometimes not been realized, and just recently (in connection with the absorption of the penetrating radiation by the atmosphere) the question has been revived in its simplest form. Consider two balloons full of air, one hermetically closed, the other with an opening. If these balloons are heated, the pressure in the closed balloon will rise and the rubber will burst eventually, but in the open balloon the pressure remains practically the same since the air can expand freely and flow out. The conditions of the atmosphere at sunrise have been compared to those in the closed balloon; it has been said that the Earth is so rapidly heated in the morning that the air (partially confined, because of its viscosity and inertia), can not expand fast enough, and the pressure rises simply because of the heating. This was offered as an explanation of the morning maximum of pressure. This opinion may, however, be proved to be wrong; the atmosphere corresponds to the air in the open balloon, because it can expand vertically fast enough and can adjust itself to the diurnal variation of temperature. Diurnal variations of pressure are really only due to corresponding changes in the weight of the atmosphere above the station, and such changes in the weight can only occur through horizontal movements of air, that is, through winds. These winds—land- and sea-breeze, mountain- and valley-breeze—may be too weak to be noticeable every day, but the systematic shift of air-masses is sufficient to be recorded by the barometer and to be brought forth in the average of many days. Since these winds are mainly local in character and depend mostly on the differential heating of different parts of the Earth's surface—land and sea, for instance—they will have a diurnal variation which is similar to that of their cause, the temperature of the air; that is, mainly a 24-hourly wave as shown in Fig. 8. This explains why the local differences in the diurnal variations of pressure are confined to the 24-hourly sine-wave, but scarcely affect the 12-hourly sine-wave.

This distinction is again brought out in Fig. 9, both on Pike's Peak and at Colorado Springs the 12-hourly pres-

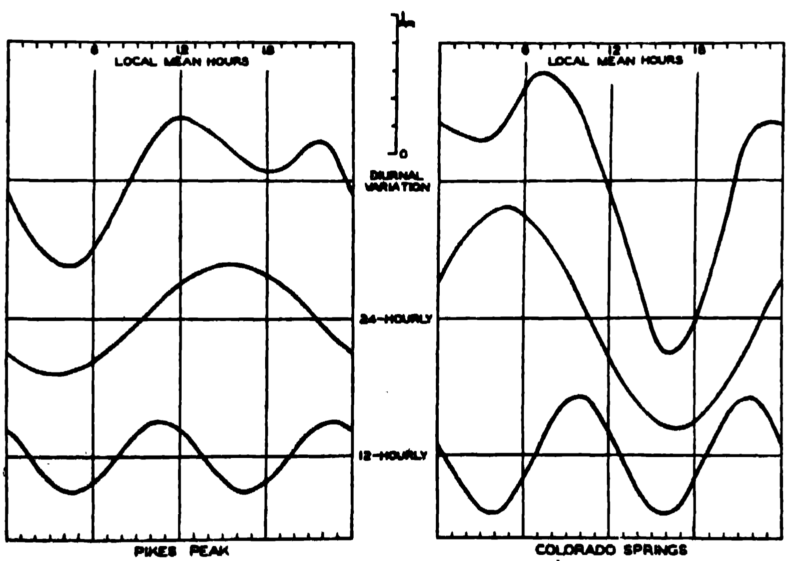

FIG. 9. HARMONIC ANALYSIS OF PRESSURE IN SUMMER.

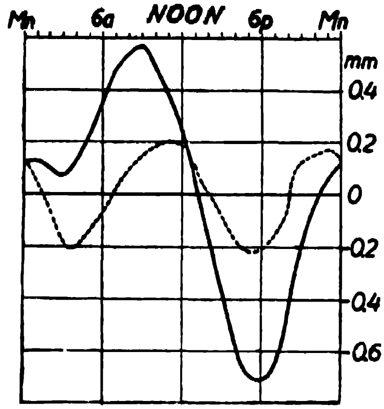

FIG. 10. DIURNAL VARIATION OF PRESSURE ON CLEAR (FULL LINE) AND CLOUDY DAYS IN JUNE AT POTSDAM, GERMANY (AFTER WIEN-HARMS).

sure-wave has its maximum near 10 o'clock in the morning and in the evening, while the 24-hour waves on the top and at the foot of the mountain are exactly reversed.

The mainly local character of the 24-hourly wave of pressure as against the universal character of the 12-hourly wave can finally be ascertained in the following way: On cloudy days, the diurnal variation of temperature is small as compared with clear days. Consequently, the shift of air between land and sea and the accompanying winds and variations of pressure will also be smaller on cloudy days. This is shown in Fig. 10; on clear days, there is only one maximum and one minimum in pressure, but, on overcast days, all local effects are diminished, and only the world-wide 12-hourly wave of pressure persists. Fig. 10, simple as it looks, is the only reliable curve of its kind which has ever been derived, because the numerous other attempts have been badly spoiled by a curious systematic curvature-effect which is connected with the selection of clear and cloudy days and has always been overlooked.

It would be tedious to show the universal character of the 12-hourly wave of pressure by more curves of the same kind. A more convenient way of representing sine-waves is explained in Fig. 11. It shows the 12-hourly wave of pressure at Washington, D. C., in winter, above in the usual way, below in the so-called harmonic dial. This is nothing but a graph of the dial of an alarm-clock, in which the hand points towards the time of maximum, while the amplitude of the wave is indicated by the hand. This simple graph replaces the curve in every way, because the form of a 12-hourly sine-wave is completely given if we know its amplitude and time

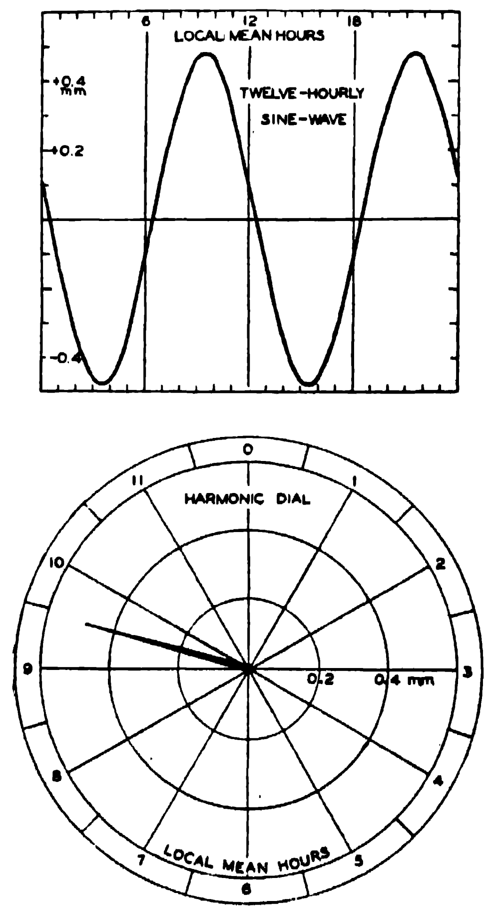

FIG. 11. ATMOSPHERIC PRESSURE FOR DECEMBER AND JANUARY, WASHINGTON, D. C.

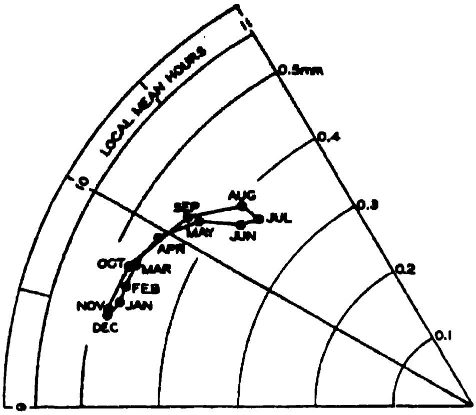

FIG. 12. HARMONIC DIAL FOR TWELVE-HOURLY WAVES OF PRESSURE, WASHINGTON, D. C.

of maximum. The harmonic dial can be further simplified by indicating the hand only by its end-point; it has then the advantage that more than one wave can be shown on the same dial. We can further omit unnecessary parts of the dial. This has been done in Fig. 12, which shows the 12-hourly waves of pressure at Washington, D. C., for every month. Only the end-points of the hands for each month are drawn and counted in succession; throughout the year, the maximum occurs between 9^h 30^m and 10^h 30^m, and the amplitude remains about 0.4 mm.

In the chart of North America (Fig. 13), harmonic dials are imagined with their center at all those meteorological stations for which the 12-hourly (or semi-diurnal) wave of pressure, in the average for the whole year, has been computed from actual observations; only the hands of the dial are shown. The amplitude diminishes from the tropical regions towards the north (from 0.9 mm in the West Indies to 0.3 mm at Cleveland and Chicago), but the maxima occur everywhere with astonishing regularity about 10 o'clock local time. Using the conception of the harmonic dial as an alarm-clock which rings at the time of the maxima, we should hear the alarm 2 hours before noon and 2 hours before midnight, progressing from east to west across the continent with a speed of about 800 miles per hour—much faster than any cyclone.

In the schematic world-chart (Fig. 14), this progressive 12-hourly wave is represented by isobars, that is, lines of

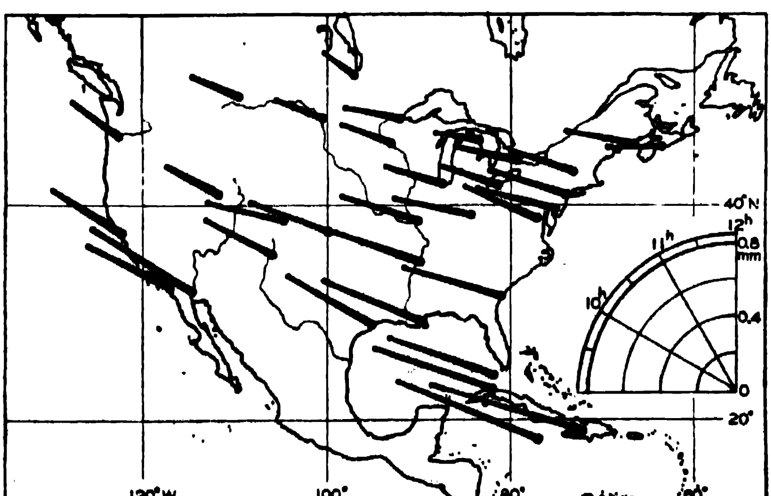

FIG. 13. SEMI-DIURNAL SOLAR WAVES OF ATMOSPHERIC PRESSURE IN NORTH AMERICA: SCHEME FOR HARMONIC DIAL SHOWN BY INSET.

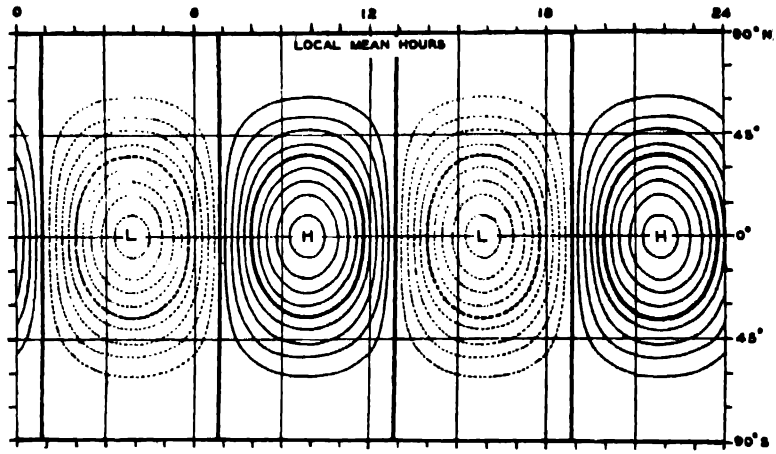

FIG. 14. WORLD CHART OF PROGRESSIVE TWELVE-HOURLY WAVE—ISOBARS 0.1 MM DISTANT (FROM NATURWISSENSCHAFTEN).

equal pressure, drawn 0.1 mm apart; as in a weather-chart, we recognize two areas of high pressure (H), centered at the equatorial points where the time is 9^h 50^m in the morning and evening, and two areas of low pressure (L) at 3^h 50^m. This double wave travels with the Sun from east to west. The chart shows how the amplitudes decrease towards the poles, from nearly 1.0 mm at the equator to 0.1 mm in 60° latitude.

In the polar caps, the 12-hourly wave is very small and seems irregular. In the harmonic dial, on the left in Fig. 15, the values of the 12-hourly pressure-wave for the polar stations north of 70° north are marked by small circles, and those for polar stations south of 65° south by small crosses. The maxima are scattered all over the dial, instead of occurring about 10 o'clock as we have seen for non-polar stations. This irregularity is, however, only apparent and turns into a striking regularity if we use, not the dial of local time, but one of universal time, for instance, Greenwich mean time. This transformation is done in the right-hand dial of Fig. 15; as though by magic, all the points arrange themselves about $11.^h5$ Greenwich time. Somewhat idealizing we can say that the alarm-clocks ring in both polar caps simultaneously. The amplitude is about 0.1 mm at the poles.

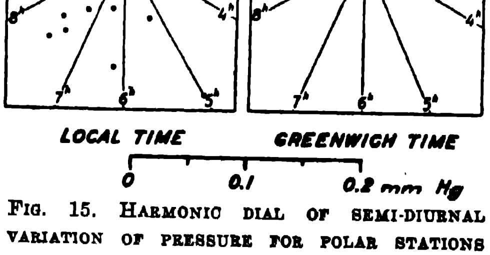

FIG. 15. HARMONIC DIAL OF SEMI-DIURNAL VARIATION OF PRESSURE FOR POLAR STATIONS NORTH OF 70° N. (CIRCLES) AND SOUTH OF 65° S. (CROSSES) (AFTER WIEN-HARMS).

Mathematical analysis can detect this polar wave also at a greater distance from the poles, where it is of course combined with the main progressive wave. An isobar chart of the polar region (Fig. 16) shows zones of high and low pressure; this wave is therefore called zonal. It is stationary, that is, the nodes (in about 35° latitude) remain fixed. The chart shows the conditions at $11^h.5$ Greenwich time (the time of maximum in the polar zones); 3 hours later there

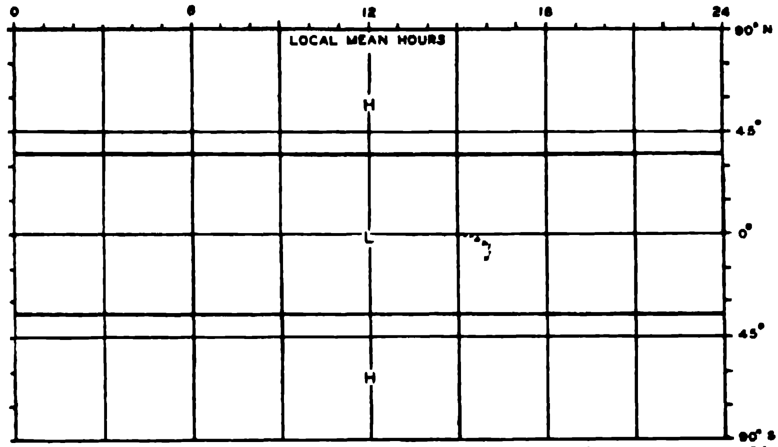

FIG. 16. WORLD CHART OF ZONAL TWELVE-HOURLY WAVE AT $11.^h5$ GREENWICH MEAN TIME (FROM NATURWISSENSCHAFTEN).

would be no pressure-differences, 6 hours later the polar caps would have low pressure and the equatorial zone high pressure, and 12 hours later the distribution of pressure would be again the same as shown in the figure.

An 8-hourly wave of pressure had long been overlooked, because the theory of the gravitational tides does not predict such a wave. It exists, however, and not merely as a mathematical fiction, but as a separate progressive wave of a strange symmetry. Fig. 17 shows, for two stations in the northern hemisphere, the 8-hourly waves for each month in harmonic dials, which, for economy, have been cut down to the form of wrist-watches, and which show only the times of the first maxima in the day, because the two others occur exactly 8 and 16 hours later. The amplitudes are small, of the order of 0.15 mm, and a bit larger at Washington than at Potsdam, but otherwise the dials for both stations show the same features. In the winter months, the first maximum occurs shortly after 2 o'clock in the morning, the first minimum, therefore, at 6 o'clock. In the summer months, the wave is exactly reversed: We read from the dial that the first maximum of pressure occurs shortly after 6 o'clock in the morning, just the time when the first minimum occurs in winter! We find this reversal from summer to winter again in the 8-hourly wave of temperature (Fig. 18); this indicates a relation of cause and effect between the 8-hourly waves of temperature and pressure which is confirmed by theory.

The world chart for the 8-hourly wave of pressure (Fig. 19) is drawn for December, that is, winter in the northern,

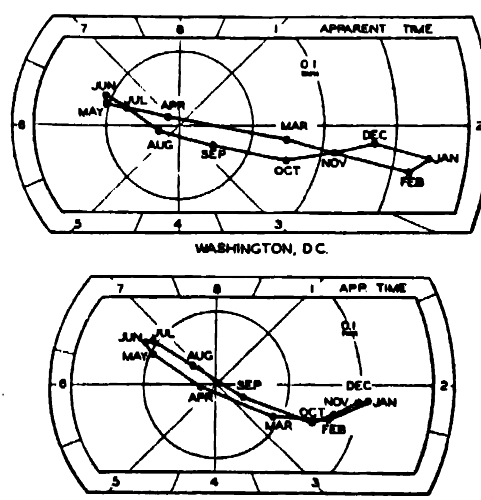

FIG. 17. HARMONIC DIALS FOR EIGHT-HOURLY WAVES OF PRESSURE, WASHINGTON, D. C., AND POTSDAM, GERMANY.

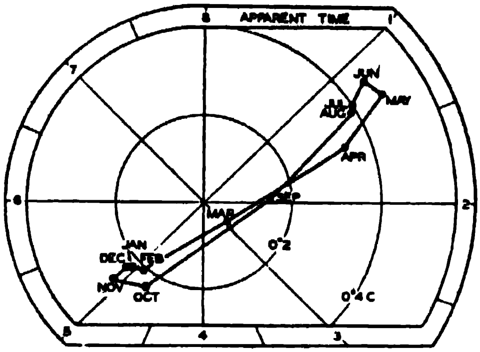

FIG. 18. HARMONIC DIAL FOR EIGHT-HOURLY WAVE OF TEMPERATURE, POTSDAM, GERMANY.

and summer in the southern hemisphere. The areas of high and low pressure are therefore opposite on both sides of the Earth's equator. The amplitude is highest, about 0.15 mm, in 30° latitude. The chart for June would look similar, but the letters *H* and *L* would exchange their places. (This world-chart does not show that the amplitude of the 8-hourly pressure-wave is smaller in summer than in winter; it contains only the relevant part, corresponding to the anti-symmetric spherical harmonic P_4^3. In other words, the monthly means of the waves are not reckoned from the origin of the dial in Fig. 17, but from the center of gravity of the twelve monthly dots, that is, the average for the whole year.)

The horizontal winds near the Earth's surface which accompany the 12- and 8-hourly pressure-waves are shown in the schematic charts in Fig. 20. The isobars in these charts are copies of characteristic parts of the diagrams Figs. 14 and 19. It is interesting to note how the wave-motion progresses towards the west, since all the wind arrows converge to the points where the high pressure will have moved after a quarter of the period (3 or 2 hours). These periodic winds are weak, less than about 2 feet per second, or about one mile per hour. If there were no other winds, an air-particle would describe regular ellipses of about 2 miles extent for the 12-hourly wave, and one third of a mile for the 8-hourly. Similar air-movements in the high layers of the atmosphere are the cause of the magnetic variations which were mentioned at the beginning.

The systematic harmonic analysis has, as we have seen, revealed regular world-wide oscillations of the atmosphere in the solar diurnal-variations of pressure. The search for corresponding influences of the Moon was first successful for tropical stations, but met great difficul-

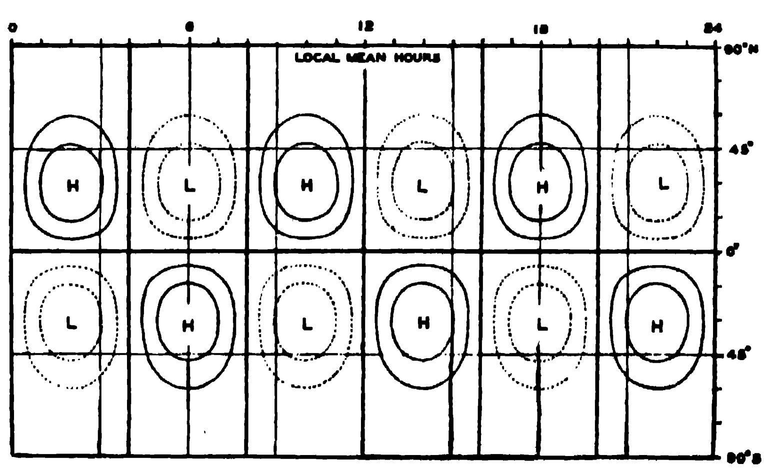

FIG. 19. WORLD CHART OF PROGRESSIVE EIGHT-HOURLY WAVE FOR DECEMBER—ISOBARS 0.5 MM DISTANT (FROM NATURWISSENSCHAFTEN).

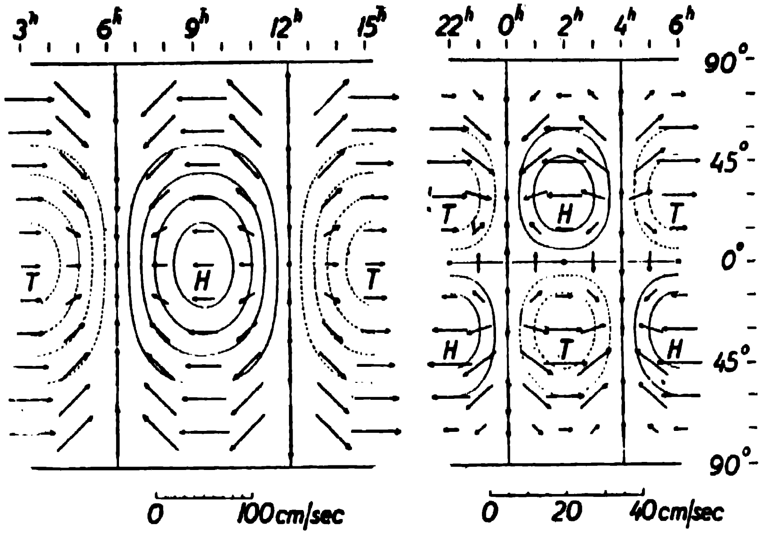

FIG. 20. CHART SHOWING HORIZONTAL AIR-MOVEMENTS IN THE PROGRESSIVE TWELVE-HOURLY (LEFT) AND EIGHT-HOURLY DIURNAL WAVES OF PRESSURE (AFTER WIEN-HARMS).

ties for stations in higher latitudes because of the great unperiodic variations of pressure which are connected with the weather changes. Laplace used nearly 5,000 barometric observations taken through eight years at Brest, and Airy used 160,000 hourly observations taken through twenty years at Greenwich, but both analyses failed, and satisfactory results have been obtained only in recent years, mostly by S. Chapman.

In principle, the calculation of a lunar variation is the same as that of a solar variation. A *solar* day is reckoned from midnight to midnight or, as the astronomers say, from one lower transit of the Sun to the next; the upper transit is noon. In the same way we may introduce a *lunar* day from one lower transit of the Moon to the next, an interval about 50 minutes longer than a solar day. The lunar day can again be divided into 24 lunar hours. Starting from our raw material, the hourly values of pressure for a number of years, we combine all pressure-observations for the first lunar hour, for the second lunar hour, etc. The result derived from 66 years of observations at Potsdam and Hamburg are

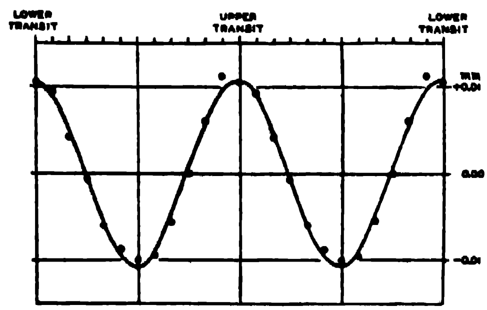

FIG. 21. AVERAGE LUNAR PRESSURE-WAVE FOR POTSDAM AND HAMBURG, GERMANY (FROM NATURWISSENSCHAFTEN).

represented by dots in Fig. 21, which fit into a beautiful sine-wave of 12 lunar hours period, a lunar semi-diurnal wave, with high pressure near the lower and upper transit of the Moon, just as tidal theory predicts. Why it was so difficult to obtain this curve is explained by the extremely small amplitude, 0.01 millimeter; the pressure is only 0.02 mm higher, when the Moon stands highest in the sky or lowest below the horizon than when the Moon is just rising or setting in the horizon. The curve, as it appears in Fig. 21, shows the actual lunar rise and fall of the mercury column of

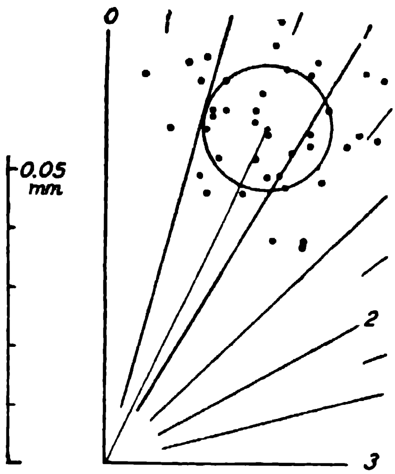

FIG. 22. SEMI-DIURNAL WAVE IN PRESSURE FOR LUNAR HOURS—BATAVIA, 1866–1905 (AFTER WIEN-HARMS).

the barometer, about 1,000 times enlarged. An ordinary barograph-curve of 40 mm width, such as that shown for Washington in Fig. 2, would, on the same scale, be about 120 feet high, and even the trace of the recording pen would appear about 8 inches wide. This minute lunar wave is, so to say, drowned in the large irregular waves of the ordinary high- and low-pressure areas, and its detection is the triumph of certain statistical methods which had to be developed for the discovery of such hidden periodicities. This improvement of the analytical methods which was necessary for the computation of the lunar tides in atmospheric pressure has sharpened the tools with which we may test the great number of other cycles and periods which have been claimed in geophysical and cosmical phenomena.

The computation of the lunar atmospheric tide is also a typical geophysical problem in another direction. The raw material from which the computation starts are readings of the barograph-curves to 0.1 mm such as 759.1 mm; the result is a curve which is accurate to 0.001 mm. It looks as though a higher precision of the original observations—to 0.01 mm, for instance, which is quite feasible—might be helpful. But this

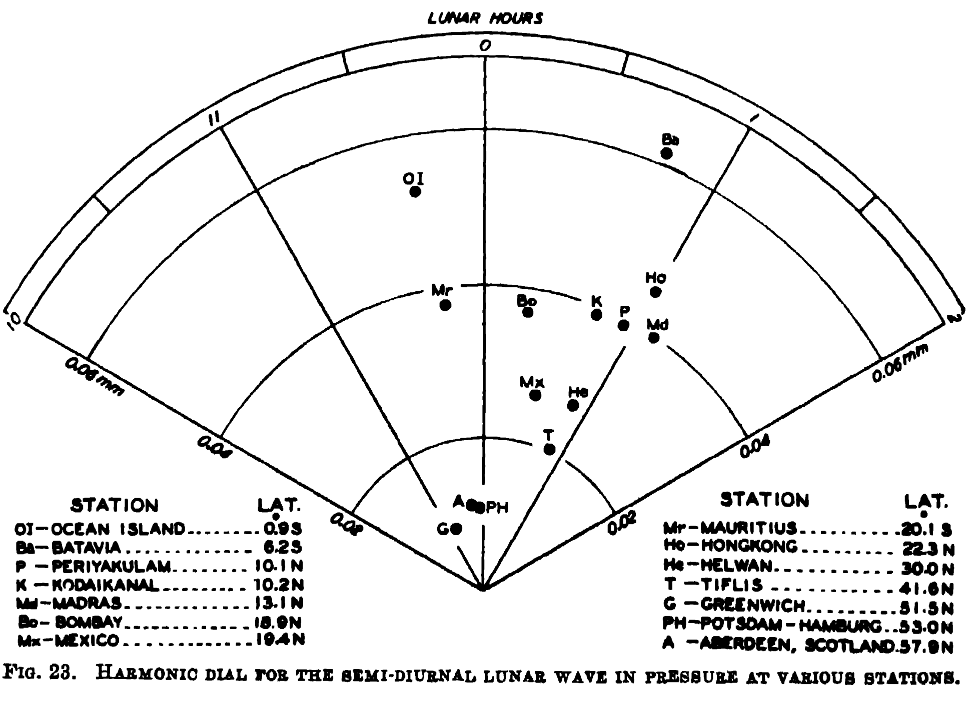

FIG. 23. HARMONIC DIAL FOR THE SEMI-DIURNAL LUNAR WAVE IN PRESSURE AT VARIOUS STATIONS.

idea is fallacious; not the observational errors but the great natural non-periodic variations of pressure hide the lunar wave. The wave can be found only by refining a great number of barometric curves in which it is so highly diluted.

The principle of these statistical methods is indicated in the harmonic dial for the lunar semi-diurnal waves in pressure at Batavia, Fig. 22. Each of the 40 dots represents the result as computed from the observations in one of the 40 years 1866–1905. The amplitude seems to vary between 0.04 and 0.08 mm, and the highest pressure occurred in some years only about 10 minutes, in others as late as one and a half hours after the transit of the Moon (marked on the dial as 0ᵃ). This scattering of the results for the single years is not to be regarded as a real change in the lunar wave from year to year, since it is only due to the difficulty of eliminating the non-lunar variations of pressure from the observations in a single year; but the amount of scattering provides us with a quantitative estimate for the reliability, the probable error, of the average lunar wave as derived from 40 years of observation.

Fig. 23 contains the results of the analyses of lunar waves in atmospheric pressure to date; in all, it represents the extract of over two millions of hourly observations. In spite of the small amplitudes (decreasing from about 0.06 mm at Batavia near the equator to 0.01 mm at Potsdam, and still less at Greenwich), high pressure occurs everywhere within one hour of the lunar transit. The small individual differences in time of the maximum can be attributed to the fact that the atmosphere is not only under the direct influence of the Moon's tidal forces, but is of course secondarily affected by the tidal movements of its under-surface, ocean and land, and the oceanic tides are locally very different, as is well known.

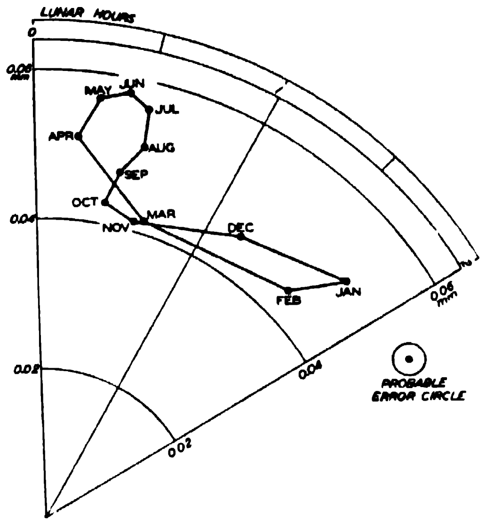

FIG. 24. SEMI-DIURNAL WAVE OF PRESSURE FOR LUNAR HOURS—AVERAGE FOR BATAVIA, BOMBAY, AND HONGKONG.

A puzzling feature of this lunar semi-diurnal wave of pressure of which we just saw the annual averages, is its systematic change in the course of a year, which is surprisingly similar all over the globe. In January, the maximum pressure occurs more than one hour later than in June, and the amplitude is also smaller (Fig. 24). This change is real, because it is far outside the range of the probable-error circles, the size of which is indicated in Fig. 24. Such circles must be imagined to be drawn around

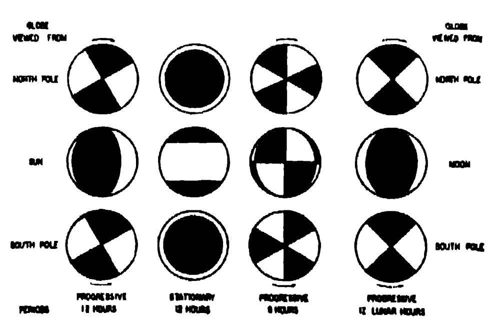

FIG. 25. SCHEME OF WORLD-WIDE OSCILLATIONS OF THE ATMOSPHERE.

each dot representing a monthly value of the lunar wave in the harmonic dial; they indicate, by their small diameter, the reliability of the monthly values, of which each is based upon about 100,000 hourly values.

The lunar wave in atmospheric pressure is one of those rare cases in which nature makes one simple large-scale experiment at a time. The Moon's heat radiation is negligible, so that the whole effect of the Moon is gravitational, truly tidal. Yet, the rise and fall of the air-pressure with the Moon entails also a slight temperature-variation; because, when air is compressed, it gets warmer. An every-day experience of this is that when air is pumped into a car-tire the valve gets hot. The compression and dilatation of the air in the lunar pressure-wave is so small that even for the tropical station Batavia theory predicts only a so-called adiabatic heating by 0.015 degree Centigrade from the lowest to the highest pressure in the lunar wave. Through the reduction of over 60 years of hourly observations of air-temperation at Batavia, this minute temperature-effect has indeed been found, and one may conclude that here in Washington a similar, though smaller, effect exists. In familiar terms, under like weather conditions, here in Washington it is about one fiftieth of a degree Fahrenheit warmer when the Moon stands highest in the sky or lowest below the horizon than when the Moon rises or sets at the horizon. Of course, the temperature-changes which accompany the weather changes are about one thousand times as large; but the lunar wave gives interesting information about the properties of the atmosphere, because it is the only case in which we can study the effect of a pure pressure-change on large air-masses without the vitiating influence of simultaneous changes in radiation.

The problems with which finally an explanation of the tidal atmospheric movements is faced are best formulated in connection with Fig. 25, which summarizes the results of the observations. It shows for each of the world-wide oscillations of the atmosphere, three schematic views of the globe from the north and south poles and from the Sun or Moon; high- and low-pressure areas are indicated in black and white. The main wave is the 12-hourly progressive solar wave, with maxima at 10 o'clock; it is that which appears clearly on the barograph-curves of tropical stations. The others, which we could obtain only by harmonic analysis of long series of observations, are the small stationary 12-hourly wave (predominant in polar regions), the 8-hourly wave with its contrast between the winter and summer hemisphere, and finally the lunar wave.

The lunar wave is most easily explained, because it has exactly the expected form of the tide produced by the Moon's gravitation. With the same certainty we can say that the 8-hourly wave is not gravitational in origin, because there is no such part in the tidal forces. In fact, it is produced by the 8-hourly wave of temperature, as was suggested by the fact that the 8-hourly waves in pressure and temperature show the same characteristic reversal from summer to winter.

The main solar 12-hourly wave of pressure is complex in nature. It consists of a gravitational part (with maxima about noon and midnight) and a thermal part (with maxima about 8 o'clock) produced by the 12-hourly wave in temperature; the combination of both gives maxima at about 10 o'clock as observed. And the zonal oscillation seems to be connected with the differences of the 12-hourly temperature-waves over land or sea.

These considerations are, however, only qualitatively satisfactory, but seem to fail quantitatively. Because, if the world-wide 8-hourly wave of pressure is produced by the small 8-hourly wave in

temperature, why do we not find a large world-wide 24-hourly pressure-wave caused by the large 24-hourly wave of temperature?

The answer may be illustrated by an electrical analogy which is nowadays perhaps more familiar to us than any mechanical analogy, namely, radio reception. For simplicity we consider a simple detector-set without amplifying tubes. Out of the great many electromagnetic oscillatory forces which are sent out by wireless stations and act incessantly on the antenna of this radio receiving set, all are suppressed except those of the period or frequency for which the set happens to be tuned, or, to use another expression, the set responds only to waves which are in resonance with the free oscillation of the set. The atmosphere, as a spherical shell, can perform a great variety of mechanical oscillations, but theory shows that only the kinds of oscillations shown in Fig. 25 are in tune with thermal or gravitational causes. All others, for instance, all the 24-hourly waves are more or less suppressed because of lack of resonance.

The detailed mathematical theory is intricate. Fortunately, for the case of an ocean of uniform depth covering the whole Earth, the tidal oscillations have been discussed by Laplace and Hough. Their formulae did not find any application whatever in that field for which they were derived, namely, in the discussion of the tides in the oceans themselves, because they do not consider the influence of the continents. But it has been possible to transfer their equations to the unlimited air-ocean, and the atmosphere is found to respond to tidal forces like a water-ocean of 5 miles depth.

The solar and lunar semi-diurnal pressure-wave (at the left and right in Fig. 25) have the same form of oscillation, but the lunar wave has a somewhat longer period, or, to use a radio expression, a lower frequenecy. The frequency per year of the solar semi-diurnal wave is, of course, $2 \times 365 = 730$, that is, the peak of the solar semi-diurnal wave passes each station 730 times per year. The frequency of the lunar semi-diurnal wave is only 705 cycles per year. The free oscillation of the atmosphere seems to be about four minutes less than 12 hours, corresponding to a frequency of 734 cycles per year. Now if we have a receiving set tuned to the frequency 734 cycles, and two stations are sending, *S* on the near frequency 730 and *M* on frequency 705, it is clear that station *S* is received with much higher intensity than station *M*, even though *M* may send out higher energy. The application to the oscillations of the atmosphere is evident, though the analogy has of course its limits.

This so-called resonance-theory was first suggested by Lord Kelvin and has been developed by Rayleigh and Margules. Though many difficulties remain, confidence in this theory has recently been strengthened. The theory predicts that an atmosphere that is nearly perfectly tuned in on the progressive solar 12-hourly wave must be also tuned in on the zonal 12-hourly wave and on the 8-hourly wave, and that is exactly what we have found in the observations.

It seems to be more or less fortuitous that the Earth's atmosphere is just so well tuned. If the Earth would lose 10 per cent. of its air, the atmosphere would be tuned in on the lunar semi-diurnal wave, and if it would lose about 30 per cent.—so that the air-pressure at Washington would decrease to the amount which we now observe at an altitude of 10,000 feet above sea-level—none of the world-wide oscillations would be observed at all.

Our survey of the atmospheric tides would not be complete without a brief comparison with similar phenomena. Tidal forces reach enormous amounts when two celestial bodies pass each other

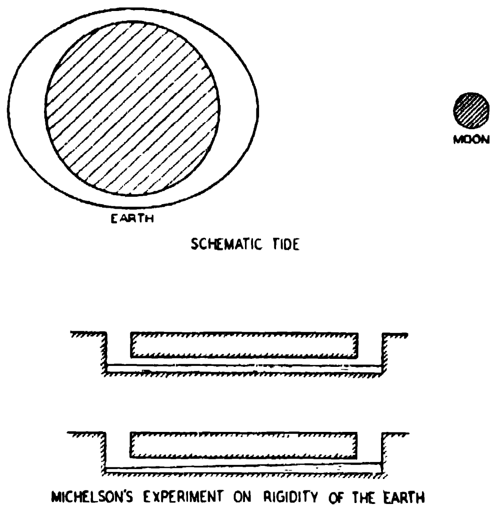

FIG. 26. SCHEMATIC TIDE AND MICHELSON'S EXPERIMENT ON RIGIDITY OF THE EARTH.

at short distance, and the birth of our planet-system has been ascribed to such an encounter of our Sun with another star during which our Sun was not hit by the other star, but broken up under the stress of the gigantic tidal forces. Under present conditions, tidal forces are small on the Earth.

A beautiful experiment of the late Dr. A. A. Michelson has demonstrated the tidal forces and their effect on the solid Earth (Fig. 26). Under the influence of the Moon's tidal forces, an ocean that covered the Earth completely would tend to take the shape illustrated at the top of the figure. Michelson buried underground pipes 500 feet long and filled them half with water. The level of this water would oscillate just as the level of an ocean. Because of the short free oscillation-period of some minutes in such a short pipe the level would adjust itself perfectly to the tidal forces and it is possible to calculate theoretical level-changes from astronomical data. Michelson measured these slight level-changes at the end of the pipe by an ingenious device and compared his observed changes with the theoretical values in order to find whether the solid Earth is perfectly rigid, or whether it is elastic. Because, if the solid Earth itself would yield perfectly to the tidal stresses, then the ground-surface would oscillate just as much as the water, and the observations would give no relative movement of water and ground at all; on the other hand, if the solid Earth were perfectly rigid, the observations would give the full theoretical value. Actually, the observed movements were seven tenths of the theoretical figures, so that the solid Earth yields only to three tenths to the tidal forces. Fig. 27 shows the tidal rise and fall of the water at the south end of a pipe stretching from north to south, for the interval from March 24 to April 21, 1917; the calculated values, which are seven tenths of the theoretical values, agree very well with the observed values. At new Moon, when Sun and Moon are in line, and at full Moon, when Sun and Moon are on opposite sides of the Earth, both pull together and produce maxima exactly at midnight and at noon; at the first and last quarter, Sun and Moon partly neutralize their influence, and the tides are small. The Moon has the greater force; therefore, the maxima occur every day about 50 minutes later.

This famous experiment not only shows the regularity of the tidal forces, but also the astonishing uniformity with which the solid Earth yields partly to the tidal stresses. No selective resonance of any kind disturbs the relation between solar and lunar tides in the solid Earth; both produce effects in the ratio of their forces. In further contrast to the atmospheric tides, no irregular effects are superposed on the minute tidal movements of the solid Earth so that instrumental precision can detect them hour by hour.

This yielding of the solid Earth has also a bearing on the theory of the atmospheric tides, because it demonstrates that the under-surface of the atmosphere

is itself in perpetual tidal motion. This is, of course, even more true of the oceans. But the coast-lines hinder the development of a great oceanic tidal wave traveling from east to west around the globe, and the tidal movements of the sea-water are resolved into a number of more or less independent oscillations of the single oceans and smaller gulfs and bays, governed in each individual case by resonance-effects. Nothing demonstrates the complicated nature of the oceanic tides better than the great differences on both ends of the Panama Canal, only about 30 miles apart: On the Pacific side, high and low water are 12 to 16 feet apart, while on the Atlantic side the rise and fall is less than one foot. It is a remarkable demonstration of the good resonance-properties of the atmosphere as a whole that the lunar atmospheric tides are so little affected by the erratic tidal movements of the surface of the oceans.

In comparison with these other tidal phenomena of the solid Earth and the oceans, the tidal oscillations of the atmosphere appear now in some ways more complicated, because they are influenced by the tidal movements of the surface of the continents and oceans, because, furthermore, temperature-variations and perhaps some other meteorological factors act in a similar way as gravitational forces, and because finally the atmospheric tides are hidden by large nonperiodic variations; on the other hand, they are more simple because the resonance-properties of the atmosphere as a whole enhance the world-wide oscillations and repress local irregularities. Fig. 28 summarizes the essential features in three schematic spectra. The first shows the gravitational and thermal causes (expressed in equilibrium-values, that is, in terms of theoretical pressure-waves, if the forced periods were much longer than the free periods); the influence of the selective resonance of the atmosphere (shown in the second spectrum) multiplies certain of these causes by high resonance-factors, and suppresses others, which results in the observed oscillations (third spectrum).

It is a fascinating task to disentangle the delicate tidal oscillations of the at-

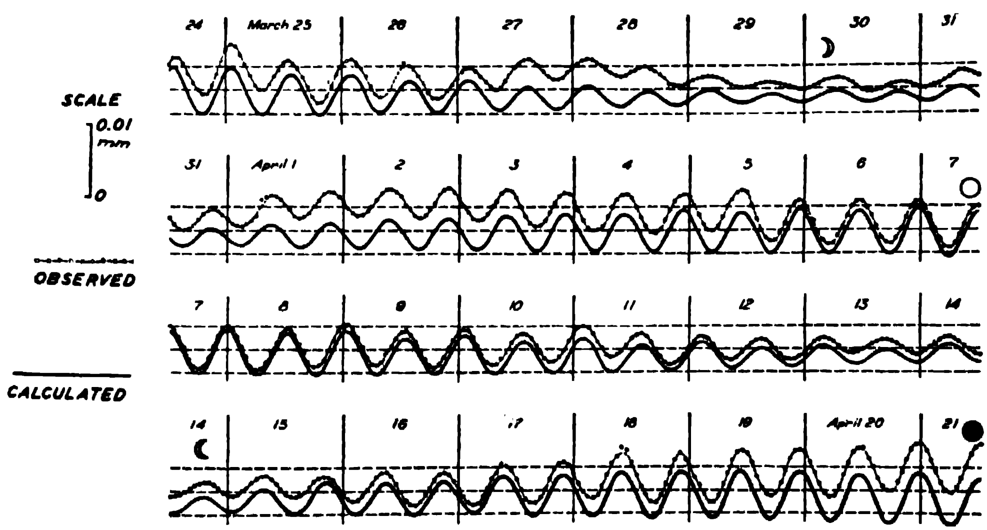

FIG. 27. TIDAL RISE AND FALL OF WATER-LEVEL AT THE END OF UNDERGROUND NORTH-SOUTH PIPE 502 FEET LONG AT YERKES OBSERVATORY (AFTER MICHELSON AND GALE) AS COMPARED WITH COMPUTED VALUES, MARCH 24–APRIL 21, 1917.

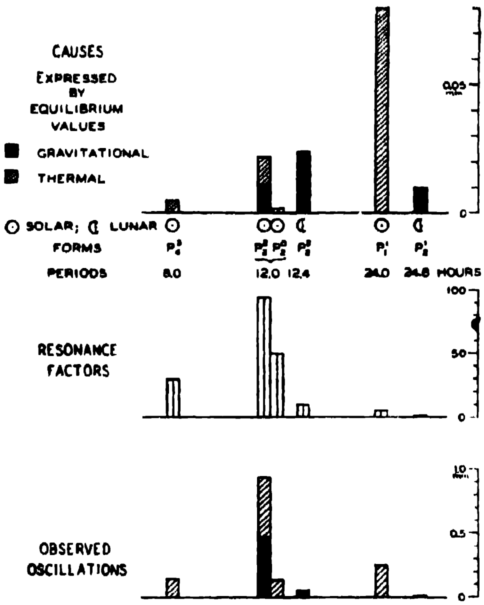

FIG. 28. SCHEMATIC SPECTRUM FOR WORLD-WIDE OSCILLATIONS OF THE ATMOSPHERE.

mosphere from the bewildering irregularities of the daily weather changes. For the weather-forecaster it might appear as a side-track, not worth while pursuing, but do not let us deceive ourselves by apparently practical considerations; those who study these minute phenomena as manifested in the pressure-waves near the ground, or in the magnetic variations as messages from great altitudes, have a similar aim to the physician who is not content to observe the more or less erratic behavior of a man but finds out more about his physical constitution by listening to the beat of his pulse.

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THIS YEAR'S ECLIPSE OF THE SUN

By JAMES STOKLEY

ASSOCIATE DIRECTOR, THE FRANKLIN INSTITUTE MUSEUM

WHEN the moon, in the course of its monthly circuits around the earth, passes between that body and the sun, producing a total solar eclipse, astronomers are always interested. And when the moon's shadow crosses a land area where there is a good chance of clear weather at the crucial moment, they do not hesitate to travel long distances in order to make the observations possible only at eclipse time. Thus, in October, 1930, two scientific groups, one from the U. S. Naval Observatory, the other from New Zealand, established themselves at Niuafoou, a nearly inaccessible little island in the Tonga group in the South Pacific Ocean. But total eclipses of the sun are not always visible only from remote parts of the world. In 1918 one was visible in the western United States, and many important observations were made. The year 1923 brought one to Southern California in September, but unfortunately the typically fine California weather failed to prevail. Few observations were made there, though astronomical parties in Mexico did have excellent conditions. When another eclipse track passed over New York, Connecticut, Rhode Island and Massachusetts early on the morning of January 24, 1925, the unexpected again happened, and the weather, along the eastern part of the track, was beautifully clear. An eclipse was visible along a path crossing England and the Scandinavian peninsula in June, 1927. Again, cloudy weather occurred over most of the track, but there were two notable exceptions. A German party in Lapland was favored with clear sky. In England, at Giggleswick, the point selected by the Astronomer Royal for the expedition of the British Royal Observatory, the day was almost completely cloudy, but a hole appeared in the clouds, surrounding the sun, just before totality. A few minutes afterwards it was raining.

With such interest shown in eclipses, it is not surprising that this year's eclipse, on Wednesday, August 31, has been eagerly awaited by astronomers, and by the general public as well, for many months. For the scientific fraternity, there is the added attraction in the United States of the meeting of the International Astronomical Union at Harvard immediately afterwards. This meeting would have been held last year, but was postponed to make it possible for foreign astronomers to combine it with the eclipse.

On August 31, according to the data published at the U. S. Naval Observatory by the Nautical Almanac Office, of which Professor James Robertson is in charge, the moon's tapering shadow first touches earth at 2:04.2 P. M., Eastern Standard Time (or 19h 4.2m G. C. T.) at a point in longitude 109° 16′ east of Greenwich and latitude 79° 36′ north. This is in the Arctic Ocean north of the East Taimir Peninsula. Thence the shadow travels northeastward and passes within a few hundred miles of the North Pole. As it then travels to the southeast, at an average speed of about two thousand miles an hour, it sweeps over Melville Sound, Prince of Wales Island, Boothia Peninsula, the District of Keewatin of the Canadian Northwest Territory, Hudson Bay, James Bay, the Province of Quebec and New England. Then it passes to sea and leaves the earth at 4:02.6 P. M., Eastern Standard Time (21h 2.6m G. C. T.) from a point in the

middle of the Atlantic Ocean with the coordinates of 40° 59′ west and 28° 27′ north, where the sun is then setting.

The path of the shadow in southern Quebec and New England is shown in detail in the accompanying map. Fig. 2 shows the shape of the shadow as it passes over this part of the earth. It is about 60 miles wide and a hundred miles long. In the middle of the eclipse track, where the widest part of the shadow crosses, the total eclipse will last about a hundred seconds. The lines crossing the shadow in Fig. 2, parallel to the edges of the path, are at ten-mile intervals and the numbers below indicate the time in seconds which that part of the shadow requires to pass a given point.

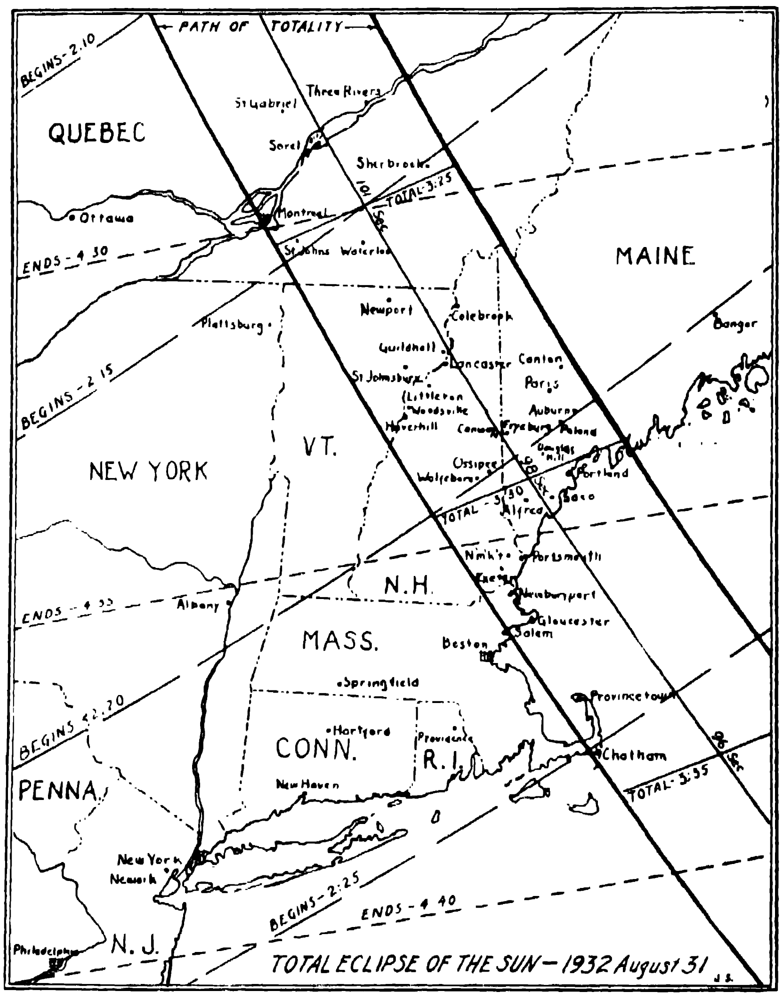


FIG. 1. PATH OF THE TOTAL ECLIPSE ON AUGUST 31, 1932.

THE ECLIPSE WILL BE SEEN AS TOTAL FROM POINTS WITHIN THE TWO HEAVY PARALLEL LINES, AND WILL LAST LONGEST ON THE CENTER LINE. THE NUMBERS ON THE CENTER LINE SHOW THE DURATION OF TOTALITY AT THAT POINT AND THE SOLID LINES CROSSING THE PATH SHOW THE TIME OF MID-TOTALITY. THE LONG LINES CROSSING THE ENTIRE MAP SHOW THE TIMES OF BEGINNING AND ENDING OF THE PARTIAL PHASES. TRACED FROM A MAP ISSUED BY THE U. S. NAUTICAL ALMANAC OFFICE.

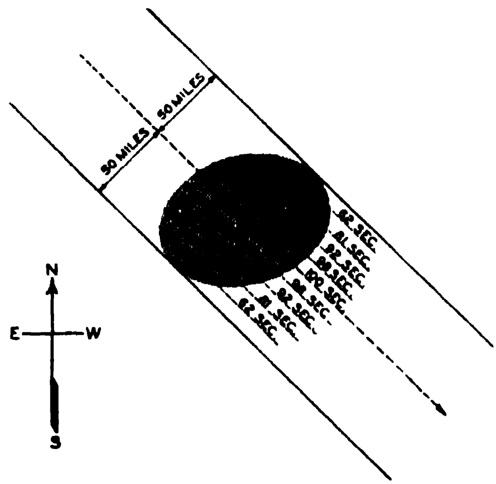


FIG. 2. MOON'S SHADOW WHEN CROSSING NEW ENGLAND.
REPRODUCED FROM A PAMPHLET ISSUED BY THE NEW ENGLAND HOTEL ASSOCIATION.

It will be seen that, while longest duration is at the center, the total eclipse will last at least a minute over a band 80 miles wide.

To an observer in the path of totality, the first warning of the coming event will occur at about 2:20 P. M., Eastern Standard Time, for a point in New Hampshire or Maine. At that time, if the observer looks at the sun, with proper protection, he will see a slight nick in the right-hand edge. The best way to look at the sun is by means of a small telescope, but of course one should never look directly at it. If the telescope is set on a firm support, and pointed to the sun, a piece of white cardboard can be held a few inches from the eyepiece in such a way that a good image of the sun is obtained. Focus can be secured by adjusting the telescope eyepiece, or by altering the distance of the card. It is usually necessary to place another card, with a small hole in the center, around the telescope like a collar, in order to shield the screen from the direct rays of the sun. The sun can be viewed directly by the time-honored smoked glass, but better yet is a dense photographic negative.

The nick which appears in the right-hand edge of the sun at about 2:20 is the moon, which is now starting to come between the sun and the earth. Gradually the nick increases in size, as more and more of the solar disc is covered. Finally, the remaining part of the sun assumes the shape of a crescent, which continues to narrow. The sun's light assumes a peculiar yellowish color, because the bluish rays from the inner solar disc, ordinarily present in sunlight, are now eliminated. The spots of light under foliage, consisting of solar images made by the pinholes formed by the interstices between the leaves, are crescent shaped, instead of round. Perhaps the shadow bands may appear. These are waves of light and shade which pass across light objects, like the white-washed side of a house, facing the sun. They are caused by streaks of varying density in the earth's atmosphere, and were very conspicuous in 1925 on the snow-covered ground. At some other eclipses they have hardly appeared at all.

Totality arrives, in New England, at about 3:30 P. M., as indicated on the map. If the observer has a clear view to some distance in the northwest, the moon's shadow can be seen approaching, like a tremendous storm-cloud, with awe-inspiring swiftness. At the same time, the last-vanishing sliver of the sun's crescent breaks up into a series of bright spots—the Baily's beads, caused by the sunlight shining through valleys on the limb of the moon, while adjacent lunar peaks already have passed the edge of the solar disc. The beads last only a moment, then, completely encircling the dark disc of the moon, now visible in its entirety, there flashes into view the magnificent corona of the sun, shining with a pale greenish light about half as brilliant as the full moon. The shape of the corona varies in step with the number of sunspots. As they are now at a minimum, the corona should probably

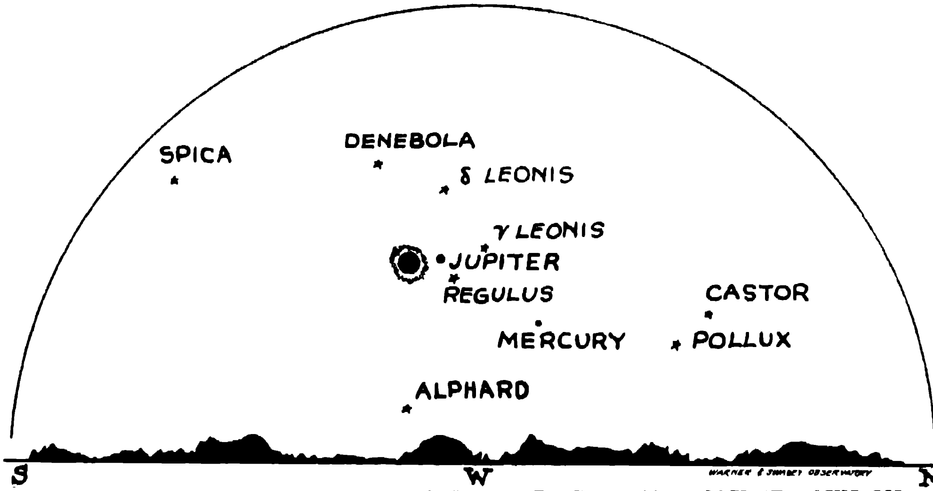


FIG. 3. STARS AND PLANETS VISIBLE AROUND THE ECLIPSED SUN ON AUGUST 31.

FROM A DRAWING PREPARED BY DR. J. J. NASSAU, OF THE WARNER AND SWASEY OBSERVATORY OF THE CASE SCHOOL OF APPLIED SCIENCE.

have several long streamers, extending out from above the sun's equator to perhaps several times its diameter. From the poles there may emerge a series of brush-like rays of light. Close to the moon's disc there may be seen some of the red solar prominences, huge flames of hydrogen and other gases. Glancing around the sky, some of the brighter stars and planets can be seen. Jupiter shines brilliantly just to the right of the sun, and Regulus is just below. Still farther to the right is Mercury. These objects, and a few others, as they will appear at the time of the eclipse, are shown in Fig. 3, in a drawing prepared by Dr. J. J. Nassau, of the Warner and Swasey Observatory, Cleveland.

But not for long can one enjoy this spectacle of the total eclipse. About a minute and forty seconds after the corona made its appearance, its outer extensions begin to fade away, and the Baily's beads reappear, this time on the right-hand edge of the sun. The shadow is seen receding rapidly to the southeast. The Baily's beads coalesce to form a thin crescent of sunlight. Possibly, to a keen eye, the inner part of the corona may hang on for a moment or two after the sun has begun to emerge from the eclipse. The first reappearing bit of the sun, made larger by irradiation in the eyes, which have become dark-adapted during the eclipse, looks much larger than it is. Coupled with the continuous circle of the inner corona, the appearance is that of a diamond ring, the name coined for the effect when it was noticed by millions in 1925. Then the crescent of sunlight grows larger, as the moon moves off the solar disc to the left. Finally, at 4:34 P. M., the last nick on the sun's limb vanishes, and the eclipse of August 31, 1932, is over.

Not until 1963 will American astronomers again have the chance to observe a total eclipse with any probability of success. The next total eclipses of the sun visible at all in the United States are scheduled for July 9, 1945, and June 30, 1954, but these both begin in the northwest at sunrise and pass over into Canada a few minutes later. On July 20, 1963, there will be an eclipse which almost duplicates the one of this year. It is visible over practically the same path, and lasts almost exactly the

same time. Relying too implicitly on the approximate charts published in Oppolzer's famous "Canon der Finsternisse" (Vienna, 1887), astronomers have not generally realized that this eclipse would be visible in the United States. Like the one of this August, it is shown in Oppolzer's maps as passing through Nova Scotia, completely missing the United States. In his introduction, as Dr. A. C. D. Crommelin has pointed out (*Observatory,* Vol. liii, p. 310), Oppolzer specifically states that the charts are merely approximate, as he has located the two ends and the middle of each track, and connected them with circular arcs, a figure quite different from the eclipse tracks. The data given in the tables in the same work show a track for this year's eclipse corresponding within a mile to that computed by the Nautical Almanac Office. Crommelin makes a plea, which the present writer seconds, that when speaking of the "path given in Oppolzer," astronomers should refer to the path computed from his data, and not that in the charts, unless specially designated. The true Oppolzer paths, for eclipses of the present century, are given by Mähler in the *Denkschriften of the Vienna Academy,* Vol. 49.

After 1963, the next favorable American eclipse will be on March 7, 1970, in Florida. This will be followed by one on February 26, 1979, in the northwestern states along a line parallel to the Canadian border. Two others will come in 2017 and 2022, the latter passing close to New York City. The next eclipse of interest to astronomers, in any part of the world after this year, will be in 1934, when one will be seen from the South Pacific Ocean on February 14. Another will be seen from Japan in 1936, on June 19, and a very long one, lasting seven minutes, from another part of the South Pacific Ocean on June 8, 1937.

It is doubtful, however, if any eclipse, for many years to come, will be seen by as many astronomers and lay observers as the one this year, assuming that favorable weather conditions permit it to be seen all along the track. A preliminary list of the expeditions, prepared by Dr. Frederick Slocum, chairman of the American Astronomical Society's eclipse committee, supplemented by several others known to the writer, shows twenty institutions represented, at nine separate points along the path of totality. The location selected by three of the groups is unknown at the time of writing. Also, several other institutions, that frequently observe eclipses, have not yet announced their plans, and it is certain that a number of other parties will be present.

Northernmost of the stations will be Parent, P. Q., a small town on the Canadian National R. R. The Royal Observatory at Greenwich, under Dr. John Jackson, chief assistant, and the Dominion Observatory at Ottawa, under Professor R. Meldrum Stewart, the director, will combine forces at Parent. Montreal, though it is near the edge of the path, has the advantage of a permanently established observatory at McGill University, and this will be used by Professor A. S. Eve, of that institution, and also by Professor A. Fowler, from the University of London. At Magog, P. Q., the party from Cambridge University, under Dr. F. J. M. Stratton, will be joined by Dr. S. A. Mitchell's group, from the McCormick Observatory of the University of Virginia. Professor C. A. Chant will head the University of Toronto's expedition, at St. Alexis, P. Q.

Coming into the United States, the Sproul Observatory of Swarthmore College will erect its equipment, including the 65-foot eclipse camera, at a point in northern Vermont. At Lancaster, N. H., will be the Mt. Wilson Observatory astronomers, under the direction of Dr. Walter S. Adams. A group represent-

ing The Franklin Institute, Philadelphia, under the writer's direction, will be located at Conway, N. H., with a coelostat camera of 85 feet focal length, as well as smaller instruments. Dr. Frederick Slocum, of the Van Vleck Observatory, Wesleyan University, has chosen Center Conway. Across the state line, at Fryeburg, Maine, will be a concentration of several parties. These will include groups from the Lick Observatory, under Professor J. H. Moore; Georgetown University, under Rev. Paul A. McNally, S.J.; the University of Michigan Observatory, under Professor H. D. Curtis; and the Dearborn Observatory of Northwestern University, under Professor Oliver J. Lee. The Perkins Observatory of Ohio Wesleyan University, under Dr. Harlan T. Stetson, its director, and the Warner and Swasey Observatory of the Case School of Applied Science, under its director, Dr. J. J. Nassau, will combine forces at Douglas Hill, Maine. At Biddeford, Maine, will be the group from the Deering Observatory, headed by Mr. Frank Deering. In addition, the Kwasan Observatory of the Kyoto Imperial University, Japan, and the Russian National Observatory, at Poulkovo, have announced plans to send expeditions, the former in charge of Professor Issei Yamamoto, and the latter of Professor A. Belopolsky.

Practic[illegible]ese parties will make direct ph[illegible]graphs of the corona, and a few, like the party of The Franklin Institute, will specialize in this field. Besides the photographs with the long focus cameras, smaller instruments will be employed, some to make a motion picture record, others, for special purposes, such as photographs in natural colors. Attempts will be made to photograph the moon's shadow from an airplane. If the edge of the shadow can be photographed on the ground, together with recognizable landmarks whose position can be accurately determined, a very precise determination can be made of the relative positions in space of the earth, moon and sun. Still other photographs will be made of the partial phases, and possibly of the shadow bands, if they appear.

At least two prominent artists will paint the eclipse in oil, a method that has been found to give a more accurate record of how an eclipse really looks than any of the photographic processes. At York Harbor, Me., Mr. Howard Russell Butler will make a painting from his own summer home. Mr. Butler has painted the last three eclipses seen in the United States, but to do so he has had to travel to Oregon in 1918, to California in 1923, and to Connecticut in 1925. The paintings are now hanging in the American Museum of Natural History, in New York. But now the mountain actually comes to Mohammed! Mr. Charles Bittinger, of Washington, D. C., and Duxbury, Mass., is also known as a painter of scientific subjects, and has already done the solar spectrum and the zodiacal light. He will paint the eclipse as a member of the party to Conway from the Franklin Institute.

Perhaps the most important eclipse observations, however, are those made with the aid of the spectroscope, particularly of the so-called "flash" spectrum, an observation that forms the specialty of Dr. H. D. Curtis and of Dr. S. A. Mitchell. Just as the last shred of the solar disc appears at the beginning of totality, and just as it first reappears at the end, the sun's atmosphere shines unmixed with light from the inner region. Its spectrum is a series of bright lines, unlike the dark line spectrum of ordinary sunlight, and photographs of this spectrum yield much important information about the sun's constitution. Other spectrum photographs, made during totality, reveal the make-up of the corona. Photo-

graphs made with the interferometer tell how the material in the corona is moving.

Despite the question raised recently by Professor Erwin Freundlich, of the Einstein Tower at Potsdam, regarding the validity of determinations of the Einstein shift of starlight passing close to the sun, as measured on eclipse photographs by Eddington, Campbell, Trumpler, Chant and others, it is not expected that any plates to confirm this effect will be made this year. The sun is in a poor field, with no bright stars nearby. Professor James Robertson, the director of the Nautical Almanac, has called attention to the good star field that will surround the February 14, 1934, eclipse, so probably that will be used for the purpose.

Away from the path of totality, of course, the effects of the total phase will be missing, but the partial eclipse will be interesting to watch. This will be visible over the entire continent of North America. The closer one is to the total eclipse track, the larger the partial eclipse will be, but as far away as southern California the moon will cover nearly a third of the sun's diameter when the eclipse is at its maximum. Even at this distance, the crescent-shaped spots of light will be noticed under trees. At points as close as Denver, Colorado; Helena, Montana, or Juneau, Alaska, the eclipse will be about fifty per cent. total. Atlanta, Georgia, will get 73 per cent., Chicago, 79 per cent., and Richmond, Virginia, 87 per cent. Philadelphia will get 93 per cent., New York 95 per cent. and Boston 99 per cent. In places as close as the last three, the peculiar yellowish color of the sunlight may be noticed, and it is possible that, where the eclipse is as much as 95 per cent. total, the shadow bands may be seen. In 1925 they were noticed at places a considerable distance from the path of totality. Also in these places, as at locations within the path, the chickens and other birds may be observed going to roost, as the darkness increases.

To the amateur astronomer, or photographer, the eclipse offers an unusual opportunity, especially if he be in the path of totality. While he can not hope to equal the work of the large cameras of the scientific parties, the amateur with a hand camera can make a very interesting record of this striking event. With a lens of 10 inches focus, the sun's image is a little less than a tenth of an inch in diameter, and if the picture is sharp, it can be enlarged considerably with quite satisfactory results. If a longer focus lens is available, it should be used. With a lens of not more than twenty or thirty inches focal length, and an exposure of not more than five seconds, the sun's motion will not be appreciable, and there is no need to mount the camera to follow the earth's diurnal motion. If the lens has a relative aperture of approximately F. 8, an exposure of perhaps two seconds can be given, though it is almost impossible to give a wrong exposure for such pictures. The inner corona is so brilliant that even an exposure of a fraction of a second will record it, while one of longer duration will overexpose the region, but will record the outer corona. Another interesting camera record can be made by taking a series of pictures at regular intervals such as every five minutes, of the partial phases and of the corona, on the same plate. If one has a 16 mm motion picture camera, it would be of interest to use it also.

But whether or not one goes to make any observations, amateur or professional, it should be remembered that Wednesday, August 31, brings the chance of a lifetime to observe an impressive and beautiful natural phenomenon, and no one interested in such things should miss it if he can possibly avoid doing so.

MODERN PSYCHOLOGY AND THE LAW: A MAJOR PROBLEM OF SOCIAL SCIENCE

By Dr. PAUL C. SQUIRES

REPRESENTATIVE OF THE PSYCHOLOGICAL CORPORATION, CLINTON, N. Y.

THE public at large has never shown a more intense interest in things legal than at the present day. Popular attention is quite naturally concentrated on the more sensational and emotion stirring phases of the law. Much talk is to be heard on every hand about the activities and mind of the criminal. The press is flooded with accounts and discussions of crime. During the past year or so the movies have virtually been obsessed with the headline topic of the criminal, crime and punishment. In the midst of all this it would seem timely to make some remarks on certain fundamental matters involved in the relations between psychology and law.

The history of law is the story of man's slow and painful progress in the direction of a more effective regulation of society. The development of the law is a vast and ever-continuing enterprise, calling for the vigorous cooperation of many realms of knowledge. Psychology, from its very nature, must become inseparably linked with such progress. On the one hand, psychological research in the field of the law is bound to illuminate many of the obscure questions of psychology itself; on the other, such research is certain to find practical expression in the betterment of the law.

ATTITUDE OF THE LEGAL PROFESSION

It is almost a truism that the rank and file of the legal profession have not been responsive to the findings and suggestions of psychologists. Of course there can be no question that a cautious and conservative attitude is amply justified; for admittedly great difficulties are to be encountered at almost every stage of psychological analysis and prediction. Yet all too often, over and above the desirable attitude of conservatism, there is plainly manifest on the part of lawyers an impulsive, violent hostility toward the teachings and resources of modern psychology. The contributions from this province are quite obviously looked upon by the great majority of lawyers as unwarranted interference with what they jealously guard as an exclusive preserve, not to be "trespassed" upon under any circumstances.

Needless to say, this hostility offers a most serious obstacle to the closer and much-needed alliance between law and psychology. That the antagonistic feeling has frequently been unduly heightened by the too hasty approach of enthusiastic psychologists to a very complex and preeminently practical problem can not be denied. Moreover, it is only rarely that psychologists have spent enough time and energy in obtaining an understanding of the actual machinery of the law and the point of view of a necessarily practical bench and bar.

The other side of the picture, however, is that lawyers as a class have not been at pains to acquaint themselves with the trends of present-day psychology. But only by so doing can they be in any position to pass competent opinion on the matter in issue. Lawyers are quick to raise the facile criticism that psychology is not a science. What if psychology is not a science? Whether it is more art than science is, as the lawyers are so fond of saying about other moot points, a "purely academic question." The only relevant

question presenting itself in this connection is whether modern psychology offers the best ground from which to attack the mental problems inevitably tied up with legal situations.

The Rise of a Legal Psychology

Originating largely in the pioneer experiments on testimony conducted by Hugo Münsterberg, of Harvard, a legal psychology has gradually been taking form. But legal psychology is a highly specialized field. Because of the great difficulties encountered in applying psychological methods and principles to the rough-and-tumble conditions of everyday law practice, it would seem essential that investigations in legal psychology be carried out whenever possible by psychologists possessed of a good legal background. The cloistered atmosphere of the academic laboratory is far removed from the emotion-charged air of the legal battle front.

The keynote of the age is cooperative research. And it is noteworthy that in the Psychological Corporation of New York City we have available a widespread organization devoted to the solution of practical problems in what has aptly been called human engineering. The corporation is interested in all problems of applied psychology, among which looms large this very intricate and socially urgent one of legal psychology.

The Criminal

Our system of criminal law rests upon an ancient foundation whose cornerstone bears the inscription "Free Will." However, the legal tests used for determining the degree of responsibility of the offender have slowly undergone the civilizing process. The "wild-beast" test, put forward in 1732 by Mr. Justice Tracy at the trial of Arnold for the attempted murder of Lord Onslow, laid down the stringent requirement that the defendant, in order to escape punishment, must be totally deprived of his memory and understanding. In 1800 this test was replaced by that of ability to distinguish between right and wrong in the abstract; the occasion of this change was the trial of Hadfield, who had made an attempt on the life of the king in Drury Lane Theater. Then came the epoch-making McNaughton trial of 1843. Daniel McNaughton, suffering from insane delusions of persecution, planned to murder Sir Robert Peel, but through mistake killed Drummond, secretary to the prime minister. The acquittal of McNaughton precipitated such wide popular dissatisfaction that the whole matter was debated in the House of Lords. The final outcome was the formulation of the now famous McNaughton Rules. These require that the defendant, in order to merit punishment, must be able to distinguish between right and wrong in respect to the particular act for the commission of which he is tried. Through these rules was accorded by the English courts the first formal recognition to what is known as "partial" insanity. The rules were also crucial in hastening the coming of the doctrine of individualization in the provinces of criminology and penology.

Mr. Chief Justice Cardozo, of the New York Court of Appeals, writing the opinion in the Schmidt murder case of 1915, has well said: "We must not, however, exaggerate the rigor of the rule by giving the word "wrong" a strained interpretation, at war with its broad and primary meaning, and least of all, if in so doing we rob the rule of all relation to the mental health and true capacity of the criminal" (216 N. Y. 324, 339). And yet, surprising as it may seem, it was not until 1919 that the New York Legislature recognized mental deficiency. The work of the mental examiners has progressed tardily in the courts, although there are signs to be

noted here and there that courts are more willing than formerly to take into consideration psychological findings. In the rape case of People *v.* Palvino, which came before the Fourth Department of the New York Appellate Division in 1926, Judge Davis, writing the opinion for a unanimous court, said: "The evidence was strong not only that the female was a mental defective, as defined by section 2 of the Mental Deficiency Law, but was mentally of the age of but seven years and two months, as determined by tests recognized by scientists and applied in this State by officials to whom is given charge of such unfortunates" (216 App. Div. 319, 321). Although there is no available space to discuss the many difficulties presented to the professional psychologist by the concept of mental age as expressed in terms of years and months, it is nevertheless certain that the above decision is most noteworthy and encouraging as an indication of the changing attitude on the part of the courts toward the findings of modern psychology.

It is much to be hoped that the time will arrive when states will establish regional boards of jurists, psychiatrists and psychologists, upon whom will devolve the arduous task of mapping out individualized treatment for those who have broken the rules of society. The monumental work of Dr. William Healy on the Judge Baker Foundation demonstrates the correct approach to the problems of crime through the study of the individual delinquent. Dr. Healy and his associates have brought to bear upon their undertaking the most approved techniques of modern psychology. The tremendous impetus given by the brilliant series of scientific investigations conducted by Dr. Healy to a more adequate comprehension of the criminal mind is now a matter of history. These researches, dealing with the psychology of the adolescent delinquent, are devoted to fundamental questions of social prophylaxis. There can be no doubt that a significant proportion of criminal careers could be prevented by the application of a carefully organized psychological service in connection with the routine of our juvenile courts; some of the courts are doing so, but their number as yet is relatively small, although growing. In order to accomplish this end more effectively the upper age limit for the juvenile court should be raised to eighteen years—sixteen is decidedly too low. The general public is well aware of the scathing denunciation launched by a recent report of the Wickersham Law Enforcement Commission against the Federal system of handling the child offender. As concerns an effective parole and probation system, there are urgently needed the extensive services of clinical psychologists for the purpose of predicting the probable boundaries within which the delinquent can be trusted out in society.

Law as a Social Science

Time was when logical perfection was the chief ideal of the doctors of the law. But for some generations there has been taking place a shift away from the hair-splittings of a medieval formalism toward the recognition of law as a psycho-social problem. The psychological attitude is irresistibly taking hold of society as a whole. This is the era of science and social realism. Psychology conceals within itself no threat of disrupting the historical continuity of our legal system, but gives splendid promise of hastening the work of confirming what is wise in the law as it now stands and rejecting what is unsound. A true science of law, and of judicial proof in particular, can be attained only by realizing the extent of the contributions and the possibilities of a psychology whose point of view, methods and techniques are steadily converging upon social welfare as the goal. No science, be it of law or anything else, can arise upon mere rule of thumb.

To pick out just one of the many problems of the criminal law: the indeterminate sentence has latent within it immense potentialities for social progress. But the successful operation of this type of sentence requires far more than a stereotyped course of procedure. It is the individual offender who is sentenced and is undergoing sentence; the indeterminate sentence can have only indifferent worth if it be not carefully adjusted to his special mental organization. The psychological approach is indispensable here.

Psychology and the Law Schools

A thorough grounding in the best that psychology has to confer should be made an essential and required part of legal education. Specially designed courses in psychology should be instituted, whose function it would be to focus psychology upon practical problems of the law. The ultimate difficulties confronting the lawyer are not as a rule those pertaining to questions of law as such—although these are complicated enough in themselves; the crucial problem is usually presented by the devious ways of human nature. There is, to be sure, no real substitute for practical experience in any profession; but every effort should be made by those in charge of professional training to insure the best possible preparation. The young law school graduate, knowing so little about the mechanisms of human behavior, goes forth to cope with situations involving at every turn men's motives and actions. Legal tradition has strongly tended to fill him with the comfortable belief that the fund of learning culled from case books and statutes is quite sufficient unto itself. But he is not long in discovering, to his dismay, that the actual state of affairs resolves itself not only into so many legal factors, but also into completely undreamed-of psychological puzzles which he is untrained to solve. Medical schools are realizing the great danger arising from sending their students out into the world without some introduction to modern psychology. In like manner, schools of law will come to realize that the training of the lawyer does not begin and end with the study of merely legal facts and principles, but that the young student of the law, so strikingly naïve in the ways of mind, should be instructed in matters psychological early during the course, and that this instruction should be explicit and systematic.

The Outlook

The law, confronted as it is to-day by baffling problems of human adjustment set by a social environment ever growing in complexity, stands in need of all the help it can get through cooperation with modern psychology. In the administration of the law it must be presumed that the humanistic point of view is controlling. And a sound humanism is founded upon the willingness to accept all the aids that the world of knowledge can offer, wherever found. The weighty duty of distributing justice to the members of society presents an unsurpassed challenge that unreservedly calls for the breaking down of the lofty barriers of false pride and prejudice erected of old between the law and a psychology that is ceaselessly striving to become scientific. There is now taking place in the law a revaluation of values. Yet the memorable words of the philosopher Nietzsche are even to-day not without significance for the law: "Because it is old, however, and smelleth musty, therefore is it the more honored. Even mould ennobleth."

The law, if it would attain the rank of a genuine social science, must come to enter into a mutual benefit association with psychology. Indications are not lacking that the hope of such an alliance will some day become a reality.

THE VERDICT OF PSYCHOLOGISTS ON WAR INSTINCTS

By Dr. JOHN M. FLETCHER

PROFESSOR OF PSYCHOLOGY, TULANE UNIVERSITY

In consideration of the social significance of the traditional doctrine concerning man's war-making instinct, it seemed highly desirable to seek what might be taken to represent a sort of official expression of opinion by psychologists regarding it. The rights of psychologists as well as the interests of society might be considered to be involved, since they, presumably, are, in their particular field of scientific inquiry, primarily concerned with laws governing human behavior. Accordingly the writer addressed a question to the members of the American Psychological Association, the returns from which he is herewith submitting. The question was framed directly to fit the concept of the war instinct which was considered to be current in popular thought. There was no intention to draw inferences as to the attitude of psychologists respecting the possibility of ending war, or respecting any particular plan of doing so. The question is a specific one concerning a psychological doctrine, which has been made current by soldiers, law-makers, journalists, economists, historians, and all sorts of other makers of public opinion. The doctrine has been promulgated as though by warrant of psychology itself, and so far it has stood without authoritative challenge. To psychologists who are familiar with the recent changes of opinion concerning instincts in general, the disparity between current tradition and scientific opinion on this matter may seem obvious enough. But this disparity has not been pointed out with sufficient effectiveness to alter popular thinking. Hence this investigation.

The question sent to the membership of the American Psychological Association was stated as follows: Do you as a psychologist hold that there are present in human nature ineradicable, instinctive factors that make war between nations inevitable?

There are 528 members of the association. Of these 378, or 70 per cent., answered. The vote stands as follows: No, 346; yes, 10; unclassified, 22.

The question was not framed so as to elicit comment, but perhaps, through interest in the subject, or else by way of making their answers more complete, many respondents added valuable observations to their votes. Some wrote letters. These comments can scarcely in justice be left out of this report. They are, moreover, of much value by way of affording a cross-sectional view on a question which is of great social import, and at the same time of considerable scientific interest.

Of those who voted in the negative 71 gave emphasis to their answers by heavy underscoring, exclamation marks, repetitions, etc. Other negative voters indicated impatience at being called upon to vote on a question which to them seemed so obvious.

Still other negative voters added comments which are quoted as follows: "Man never loses his instinctive desires and trends, but within historical times he has evolved ethically to such a point that he controls them better than he did 4,000 years ago. The process will continue, and in the course of time there will be no wars."—*E. S. Abbot.* "Instincts can make for peace as well as war."—*L. Ackerson.* "There are elements that make one stand for one's rights, but there is a natural balance between them and the several socializing elements that lead even more strongly to mutual understanding and cooperation."—*C. H. Bean.* "The human

being has few or no ineradicable tendencies."—*J. V. Breitwieser.* "While I am a strong 'hereditarian' as regards fundamental tendencies in human nature, I do not see how any thinking person can believe in an 'instinct for war' or for the complex emotions which produce war."—*J. A. Charters.* "Absolutely no instinctive process of this or any other kind."—*H. W. Crane.* "Adequate universal education will show its (war's) medievalism and barbarism."—*G. V. N. Dearborn.* "There *may* be pugnacious instincts, but they certainly don't make war inevitable."—*H. B. English.* "No. Such a view is tommyrot, bosh."—*G. A. Feingold.* "No! Nothing that intelligence and education can not eradicate."—*H. H. Goddard.* "We may have a pugnacious instinct, but it can be controlled, as experience amply shows." —*S. J. Holmes.* "It (war) is social degeneration comparable to individual insanity."—*P. Hughes.* "No. What d.f. does?"—*H. M. Johnson.* "No. Don't be silly. Disputes between individuals may lead to war between nations, but what ever made any one think that it was an instinct?" In a subsequent letter the same respondent said, "I know that it is a favorite political device to say that the people's pugnacious instinct has been aroused and that war is, or was, inevitable. Such a statement is *silly,*—in the true sense of this word, since it does proceed from and is characterized by lack of wisdom."—*C. Landis.* "There are no instincts and nothing is ineradicable in course of evolution."—*W. M. Marston.* "Some strife between individuals we shall probably always have; but nations are artificial units, and wars between them can be kept up only by deliberate propaganda." —*M. F. Martin.* "Nonsense! Why blame the instincts for our stupidity?"—*H. Meltzer.* "The abolition of duels in Anglo-Saxon society is a striking and suggestive fact worth remembering."—*Adolf Meyer.* "Positively *not.* Any one who thinks so is densely ignorant of political affairs. Wars are artificial, commercial, strategic, political, trumped up and forced upon us."—*A. S. Otis.* "Primitive man fought over roots and berries; we over markets. Cooperation, founded upon (equally innate) sympathy and gregariousness, seems a possible solution—when leaders are sane."—*S. M. Ritter.* "No. I regard war as a social form of behavior."—*E. A. Shaw.* "No. As evidenced in the reduction of warfare between nations through international social, political, and economic progress."—*A. M. Snyder.* "No. I believe they (instinctive factors) can be disciplined and controlled by police power."—*D. Starch.* "It is conceivable that other methods of settling disagreements may yet be found,—methods more effective and socially more acceptable." —*E. T. Sullivan.* "War is due to something not original; the clash of 'opinions.'"—*J. W. Todd.* "Individuals engineer war and all other cooperative large scale operations of society."—*H. A. Toops.* "No, on the existence of a 'fighting instinct.' If there were, their manifestation or expression in war, I believe, would not be 'inevitable,' unless by *definition* an instinct and its specific form of expression are inseparable."—*M. C. Tufts.* "The instinctive tendencies are subject to training."—*J. H. White.* "No. No modern psychologist holds such a view."—*J. U. Yarborough.* "Not at all; only if one is guided by the baser elements of his native disposition." —*M. J. Zigler.*

Besides those who, as above shown, added reinforcements to their negative answers there are others who added reservations or modifications. These are quoted as follows: "Not if 'nations' give up some of their silly independence and manufactured nationalism. It is precisely the same problem as that of a class war. When it comes to racial expansion the problem is harder."—*H. A. Aikins.* "It seems reasonable to me to believe that a time will at length be reached in the course of human progress when these factors will be sufficiently controlled to lead to adjustment of differences with-

out resort to war."—*M. L. Ashley.* "Not much to judge on, but would like to say 'No.' "—*H. J. Baker.* "We could get rid of formal war, but there would still be criminal nations that need policing and punishment. The social problem of war is like the individual problem of crime."—*E. G. Boring.* "No. But of course I don't know whether I am right or not."—*D. R. Brimhall.* "The struggle for existence, for power, will always cause conflict in some form, but not necessarily war as we now understand it."—*K. Brousseau.* "No. I doubt whether instincts can be *uprooted* or should be."—*L. W. Cole.* "It seems that many of the factors underlying war are based on instinctive tendencies, but, since such tendencies are subject to control, the inevitableness of war is very doubtful."—*J. E. De Camp.* "Stated in terms of what is most probable, I would say there are probably no such factors."—*R. M. Elliott.* "No, though I think there are enough such factors to make its (war's) prevention very difficult."—*M. R. Fernald.* "Not inevitable but likely."—*S. Froeberg.* "No, if you mean by 'ineradicable' that the expression of instincts cannot be altered by training."—*J. P. Guilford.* "I would not 'eradicate' any unlearned tendency, but 'modify' or 'develop' it through experience, which is education."—*F. M. Hamilton.* "Instinctive tendencies but not ineradicable."—*S. B. Heckman.* "No; likely, but not inevitable."—*E. N. Henderson.* "War is natural relief to adverse economic conditions that result from crowding. A civilization that provides adequate sustenance automatically makes war unnecessary."—*J. P. Hylan.* "No. Though they, together with our forms of social and political organization, will make wars highly probable for the next few hundred years."—*H. D. Kitson.* "No, with reservations."—*C. L. Kjerstad.* "Not inevitable but more probable than a 50–50 change."—*F. B. Knight.* "No, but there are inherent needs and the competition for the means of satisfying these needs tends in a measure toward war."—*F. H. Lund.* "No, but they do make peace and friendly relations difficult. It is a long road to travel to international peace, but undoubtedly we are already far on the way."—*M. J. Mayo.* "No. I could amplify this position if you ask for factors (*e.g.*, conflicting self-interests) that are based upon more general drives, as hunger, self-satisfaction, etc."—*N. C. Meier.* "There may be such instinctive factors but I believe they can be sublimated into activities that will prevent war."—*R. C. Metcalf.* "Original nature with adequate stimuli does favor war between nations."—*W. S. Miller.* "There are present in human nature instinctive factors that make war between nations highly probable."—*D. G. Paterson.* "No, although the complexity and remoteness of a world order may be beyond average human comprehension. This would be absence of factors (not positive instinctive factors)."—*W. T. Root.* "No, but these factors are difficult to control, and a gain in one period is likely to be nearly lost by a later reversal. We have here simply a learning curve which, in the case of international stability, must be close to the origin and highly variable."—*G. S. Snoddy.* "Are present but not ineradicable."—*M. A. Tinker.* "As human beings we have common instincts. These can be increased into a common plan by ties of service that will banish the destructive war spirit. But this condition is still far removed."—*A. W. Trettien.* "No, but that does not settle the matter by a long shot. It is inevitability versus probability. And the probability may be very high, high enough for a very good bet, say, a 1000 to one."—*J. P. Turner.* "No. But I do not mean that the eradication of war will be easy."—*J. E. W. Wallin.* "Since war has many times in the past, through the operation of ineradicable, instinctive factors in human nature, been avoided, obviously it is not inevitable. If the following question be substituted: Do you think that instinctive, ineradicable factors will

ever make war between nations impossible for the rest of time, I would answer 'No.' Only economic pressure can make war impossible. Instinctive factors work both for it and against it."—*M. F. Washburn*.

In a personal communication, too lengthy to be included, an opinion was received, the gist of which seems to be that war, while formerly necessary for the preservation of the human species, has become atavistic, and, like a physical organ that "has played its rôle," would have disappeared but for the fact that it has been "pampered and cherished." This atavistic "war instinct has become the tyrant of humanity." If it can not be abolished "all civilized mankind will die out in a geologically very short period."—*L. Hoesch-Ernst*.

Of the 10 persons who voted in the affirmative 7 gave unequivocal answers without comment. Three gave answers modified as follows: "Yes, for a long time. Maybe could breed it out after a while—doubt if education alone would do it."—*H. E. Burtt*. "Yes, when operating through *crowd behavior*."—*L. W. Kline*. "Yes. This does not imply an 'instinct to make war.' "—*L. H. Lanier*.

Among the 22 who gave unclassifiable replies some had no positive opinion, and some gave equivocal answers, while others avoided categorical answers by introducing different questions and interpretations of their own. "Evidence insufficient to justify an opinion."—*K. S. Lashley*. Only one respondent denied that the problem was a psychological one: "This seems to me to be a problem for the historian of the future rather than for the psychologist of the present."—*G. H. Kent*.

It is possible that of these 22 unclassified answers 8 might legitimately be added to the 346 negative answers reported above. These are as follows: "Instinctive factors make contest but not war inevitable. The way to eliminate war is probably to eliminate nations."—*E. Culler*. "Under present conditions, yes. With suitable international laws and means of enforcement, no."—*C. W. Darrow*. "Yes, but not that make nationality inevitable."—*H. K. Nixon*. "A combination of factors." —*D. E. Phillips*. "Utterly impossible to answer categorically. There are apparently human tendencies which make for friction and strife (anger, fear, etc.) and other tendencies which make for peace. Education and social organization turn the balance."—*E. B. Skaggs*. "The instinct of self-preservation may be developed into an impulse to fight in every normal man and woman."—*M. K. Smith*. "I feel that much, if not all, of what causes war lies deep in original nature. What *universal* education may be able to do hath not yet been revealed."—*F. M. Teagarden*. "I believe *conflict* psychologically inevitable, but international warfare may disappear if our culture changes."—*K. Young*.

Conclusion

It is to be borne in mind that the question submitted did not inquire as to the existence or non-existence in human nature of pugnacious, competitive or predatory tendencies. Nor did it deal with the question as to whether or not conflicting claims and clashes of interests must continue to arise between nations. But, assuming that such conflicts of interest shall arise, the question asked whether or not the *mode of adjustment* of these conflicts is specifically pre-determined by inherited reaction patterns of a sort that must inevitably lead to war, as traditional opinion has maintained. The conclusion, which seems evident on the face of the returns here submitted, I venture to state in answer to the above questions as follows: Without raising the issue as to the inevitability of conflicting claims and interests arising between nations, American psychologists are almost unanimously agreed that the traditional opinion that instincts determine the mode of adjustment of these conflicts is without scientific warrant.

ARIZONA THROUGH THE AGES

By EDWIN D. McKEE

PARK NATURALIST, GRAND CANYON NATIONAL PARK

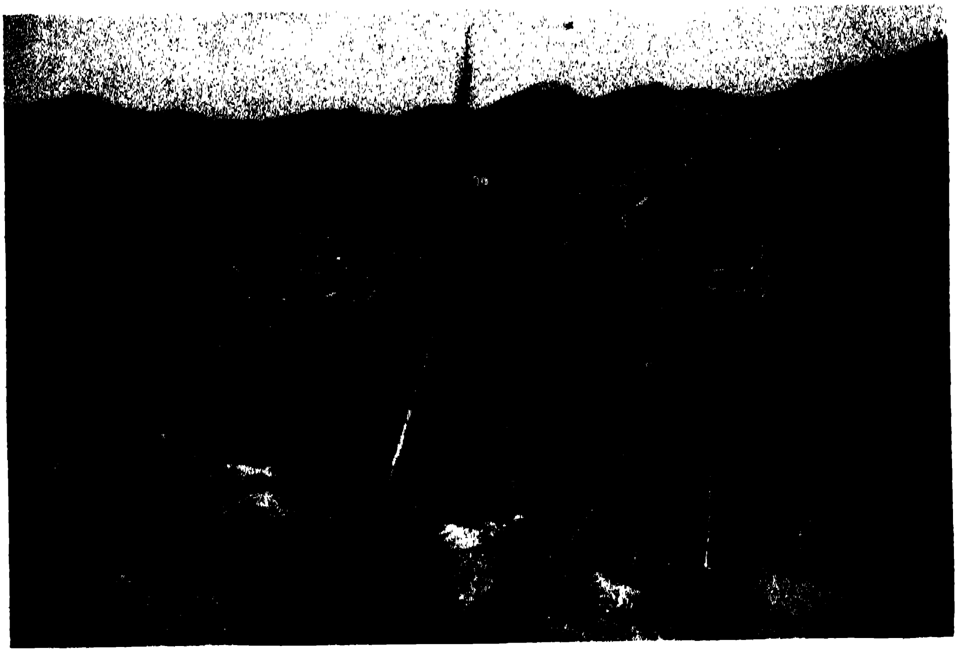
THE great desert region of the American Southwest finds much of its finest expression in the state of Arizona. Whether among the mountains, in the valleys or on the great plateau of that state the weird yet friendly landscapes have a character which a semi-arid climate alone can give. More remarkable then is the great diversity of land forms which make up the geology of this region. From north to south there are three large and vastly different areas. The high, level plateau of northern Arizona, with its mesas and tablelands, is in strong contrast to the rugged mountain area which extends from northwest to southeast through the central part of the state. Again, the famous basin range area of southern Arizona, where wide flat valleys are bordered by rugged mountain ranges, differs widely from either of the other provinces. Little wonder is it that geologist and artist alike find much to please them here.

The proverbial expression "eternal hills" is about as close to being both literally and figuratively correct when applied to the mountains of central Arizona as to any place in the world. "Rock of Ages" might perhaps be even more aptly ascribed to that ancient land, for the rocks which are responsible for much of its beauty are as old as any known to-day. They form what the geologist calls a "positive area"—a region which apparently has throughout history remained as high country and so evaded being covered by encroaching seas. While the whole of the present Colorado Plateau of northern Arizona and likewise most of the southern part of this state have been raised above and lowered beneath the level of the sea many times during the passing of geologic time, and have had great layers of sand, mud and lime deposited on their surfaces, the region of the Mazatzal Mountains, Prescott, and southwestward has with one probable exception stood aloof. For this reason it has aptly been referred to as "the ancient Mazatzal-land."

Crystalline rocks of the first era of the earth's history are found in Arizona not alone in the central mountain area, but also to the north at the bottom of the Grand Canyon and to the south, where they form the bases of many mountain ranges. Unfortunately knowledge concerning them is extremely limited, since they have been so contorted and compressed that both their original texture and composition have been altered. They stand to-day as monuments to the vast eons of time whose destructive powers they have survived.

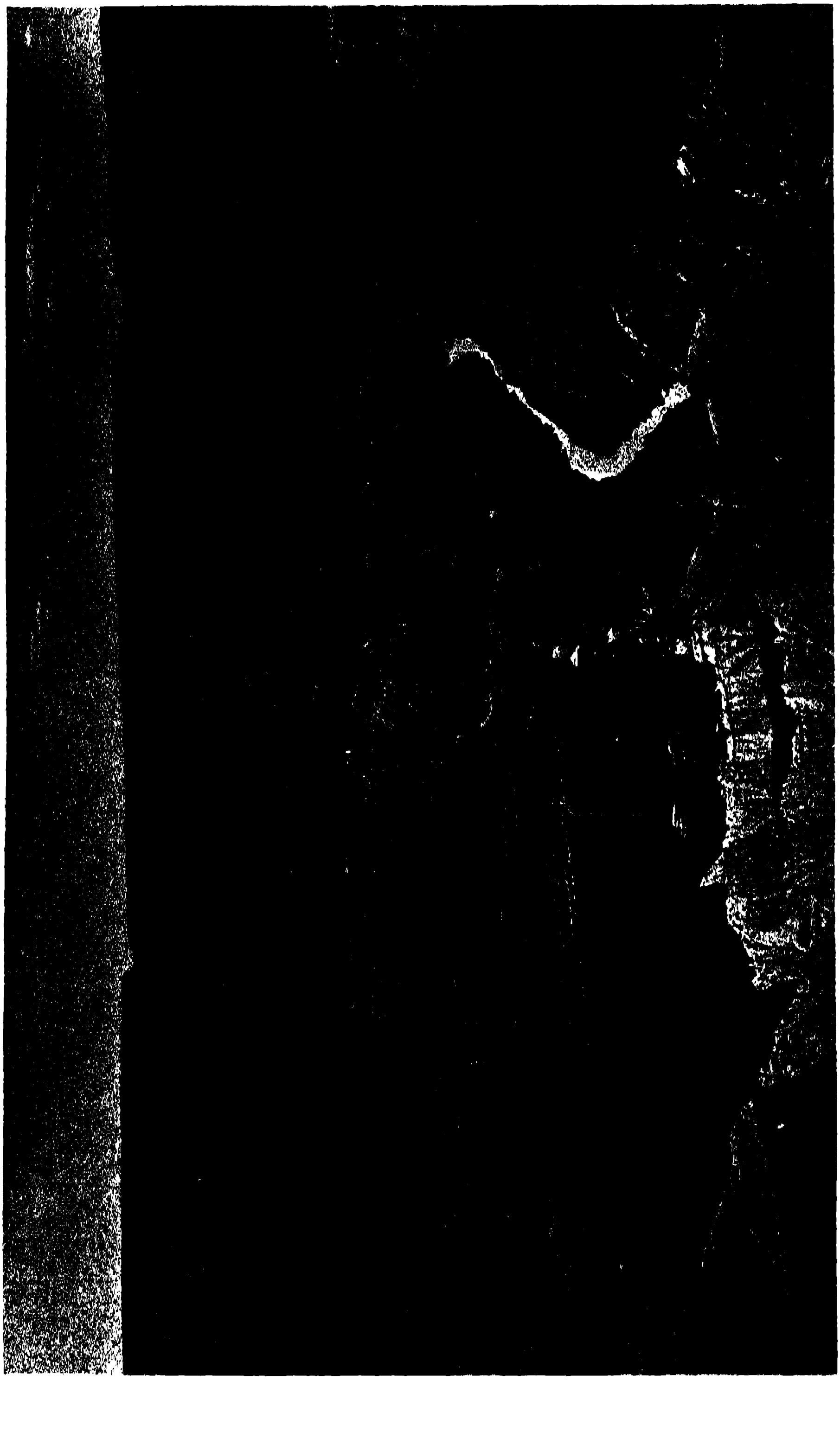
Another great series of rocks—those of the second era—is also represented in many parts of Arizona. These, though only slightly changed from their original condition, and similar in most respects to rocks forming to-day, have yielded but little of the story of their origin and formation. As yet the only definite traces of life found in them are the reefs built by primitive types of plants.

The discovery in many parts of Arizona of very primitive forms of animal life preserved as fossils marks the beginning of the next—the third great chapter of geologic history. Not only do these fossils add much to our knowledge of ancestral life and to our interest in the rocks containing them, but also they often enable us to reconstruct, with the aid of a little imagination, a very definite picture of various ancient land-



BISBEE, THE COPPER TOWN,
SURROUNDED BY ROCKS OF EARLY GEOLOGIC PERIODS.

SCENE IN THE PETRIFIED FOREST NATIONAL MONUMENT.



National Park Service.

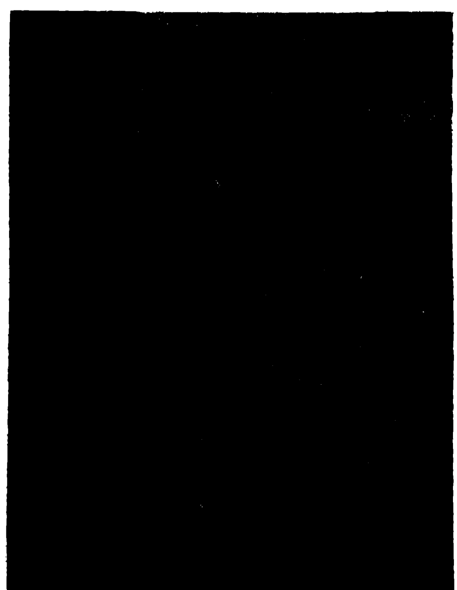
THE GRAND CANYON OF ARIZONA.

MUCH OF THE EARTH'S EARLY HISTORY IS REPRESENTED IN THE ROCK LAYERS OF ITS WALLS.

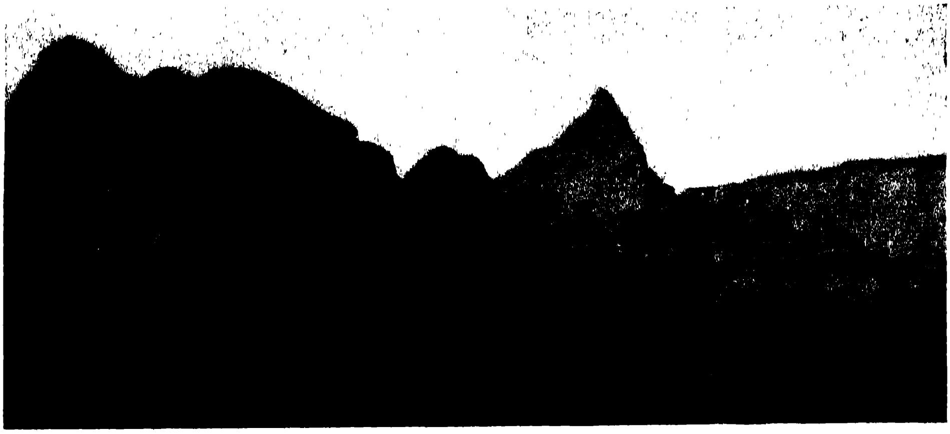
THE GILA RIVER
AMONG THE MESCAL MOUNTAINS, WHERE A FINE CROSS-SECTION OF GEOLOGIC HISTORY IS EXPOSED.

scapes of the past. We know, for instance, that large parts of the region were beneath shallow inland seas several times in that distant past and that many of the great strata of rock were formed as accumulations of limes, sands and muds beneath these seas. We know also that in the oldest rocks of this group are found only the traces of very primitive sea animals, such as shell types and crab-like creatures; that in those of later stages are found the evidences of early fish, as represented by plates or scales and teeth; and that in those rocks formed during the last part there are preserved very large forms of sea life in some places; and early land plants and four-footed animals in others. Truly, the succession and development of life as found in the series of strata of this chapter is striking. In northern Arizona it is extremely impressive as found in the upper two thirds of the Grand Canyon—layer upon layer as they were formed. Just as complete but less easily observed than the Grand Canyon series of strata are those found in many of the mountain ranges of southeastern Arizona. There the layers have been steeply tilted during mountain-making movements of more recent date, so that in order to travel from oldest to youngest one must traverse the mountains from east to west. Excellent examples of these cross-sections of history, replete with fossil life of many descriptions, are found near Globe, Tucson and Bisbee. Central and western Arizona alone remained as high country throughout practically all that great era while seas came in and retreated from the extensive basins on all sides many times. These scenes shifted continually, but always the low country was being built up, the high country eroded away, and life continued along its course of progress.

A visit to Arizona is scarcely complete without a trip into the beautiful Painted Desert in the north central



ROCK MADE OF FOSSIL SAND DUNES, PAINTED DESERT REGION.



SANDSTONES AND MUDROCKS
FORMED IN SHALLOW WATER, BLUE CANYON.

part. Here one finds scenery which is unique in many respects. There are brilliant red cliffs, flat-topped mesas, rounded blue and green hills of marl, and many other peculiar land forms which give this region a character of its own. It seems very appropriate, therefore, that the rocks of the gaudy Painted Desert should have a spectacular and thrilling history of their own.

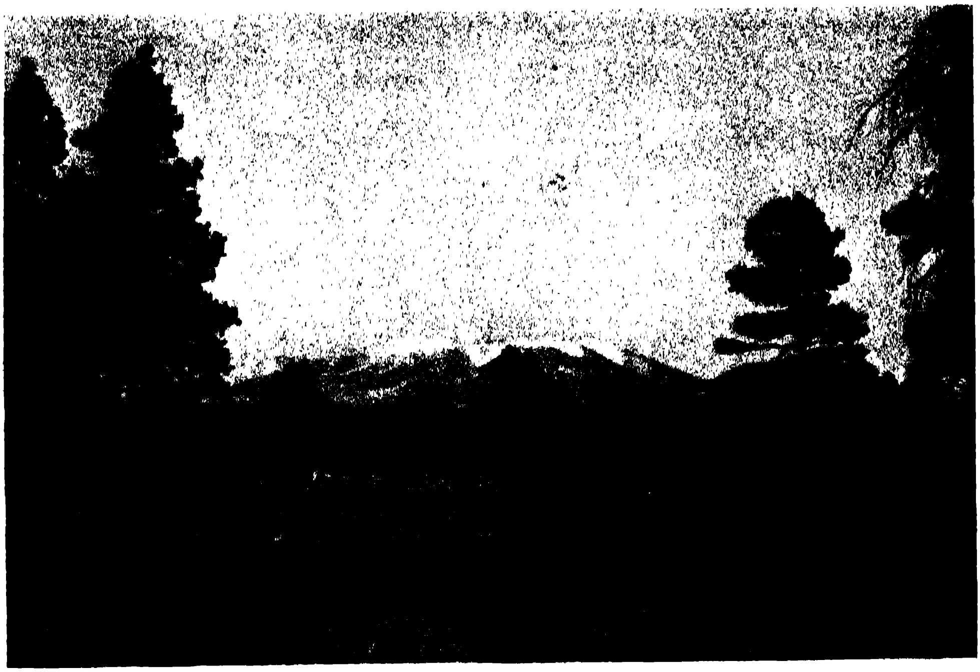
They represent periods more recent by many millions of years than any of those already described. They were formed during the famous "age of dinosaurs," and are the results of vast accumulations of pebbles, sands, limes and muds. Some of the strata were formed beneath the sea and in them are found seashells of many varieties. Others are the deposits of ancient flood

THE PUEBLO OF WALPI
BUILT ON ROCKS FORMED BENEATH THE SEA.

OATMAN,
A GOLD-MINING TOWN, LOCATED AMONG ANCIENT VOLCANIC CONES.

plains or river deltas which have preserved the tracks and bones of dinosaurs and other ancient reptiles, as well as great logs of wood which were long ago turned to stone. In the Petrified Forest National Monument in northern Arizona may be seen some of the most spectacular and beautiful examples of such petrified logs found anywhere in the world. But scenes changed many times during that great chapter, and we find that each stratum has a very distinct though equally fascinating history. The sandstone of the Vermilion Cliffs, which forms the walls of Zion Canyon and out of which has been carved the beautiful Rainbow Bridge, was built up in a great desert area as the accumulation of sand dunes. Again, at a still later date the region was quite humid with the formation of coal beds along coastal plains. The rocks of lovely little Coal and Blue Canyons and the towering Hopi mesas bear witness of the presence of coal-forming and then marine conditions in this region. Only the

ON THE NAVAJO INDIAN RESERVATION.
MONUMENTS OF FORMER ERUPTIVE ACTIVITY AND REMNANTS OF EROSION.



SAN FRANCISCO MOUNTAIN, AN EXTINCT VOLCANO.

last part of the fourth great era is represented by the exposed rocks in other parts of Arizona.

The events of the fifth and last chapter of the earth's history are recorded throughout Arizona not in rock strata, as are the older ones, but by the great displays of volcanic activity and by the many wonderful features of erosion. Most of the long ranges of jagged mountains in southern Arizona, the lofty White Mountains farther north and east, and the cone-shaped San Francisco Peaks of northern Arizona, as well as many black lava flows and other characters of the landscape, are all results of eruptive activity during "the age of mammals." A few lake deposits of gravels and sands containing the remains of elephants, camels, bison and other extinct animals have been found, showing that such creatures roamed over the region not far back in history. But the greatest story of this most recent chapter is that of erosion—the wearing down of the high country throughout the state and the sculpturing of the landscape during a vast number of years. All the scenic features for which Arizona is noted to-day—its canyons, its mountains, its mesas and its valleys—are the results of the ever-working forces of erosion in this arid region, and due to their success the magnificent history of the older rocks, extending back through the ages, has been made available to those who care to read its chapters.

RARE BOOKS IN THE COAST AND GEODETIC SURVEY LIBRARY

By HUGH H. HARTLEY

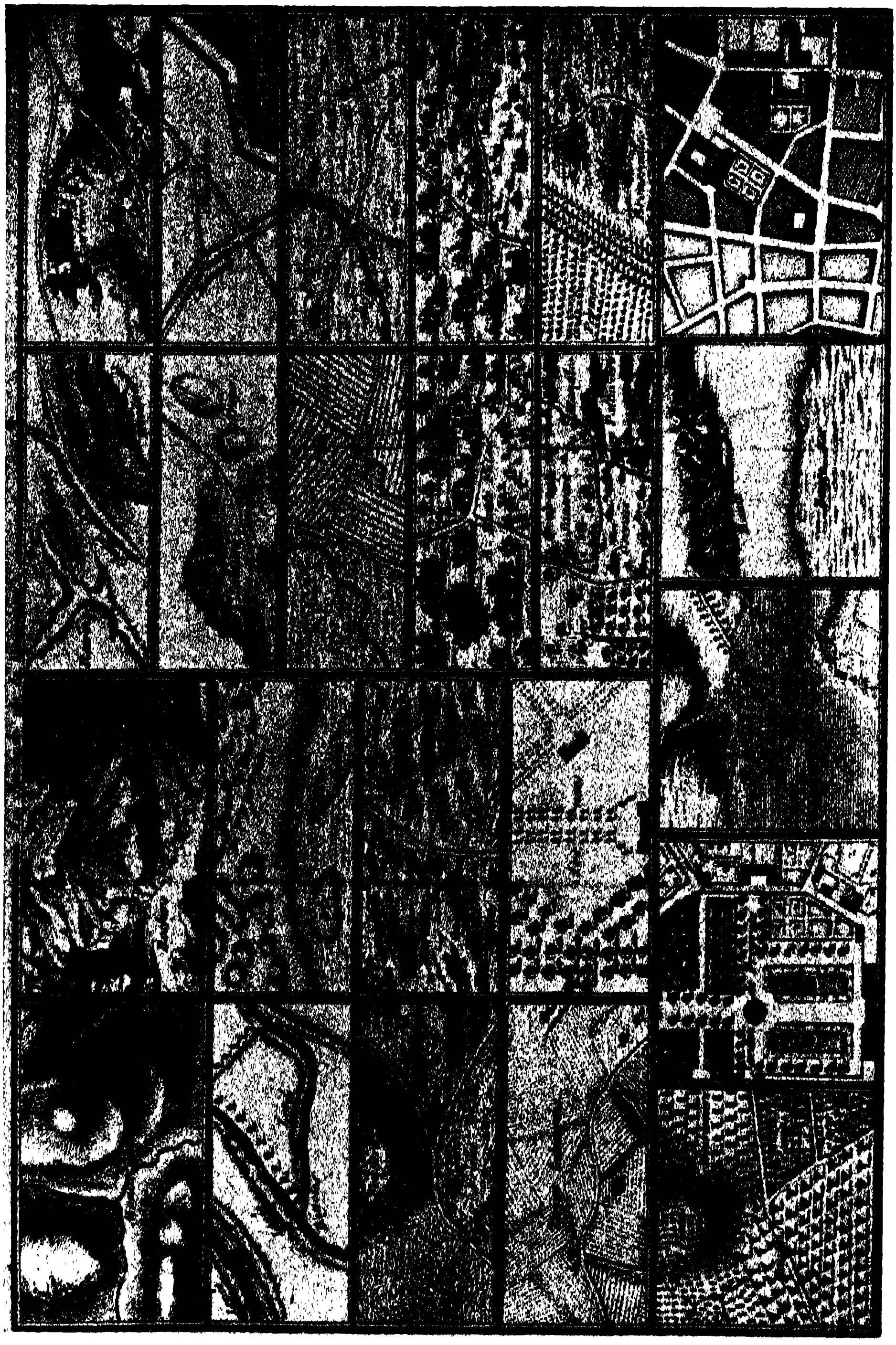
LIBRARIAN, U. S. COAST AND GEODETIC SURVEY

AMONG the extensive collection of works regarding the major subjects of geophysics, assembled to aid the scientific personnel of the Coast and Geodetic Survey in the conduct of the duties with which it is charged by legislation, the technical library of the Coast and Geodetic Survey is the fortunate possessor of numerous rare old books on astronomy, geodesy, mathematics, mechanics, terrestrial magnetism and early voyages. Many are in a splendid state of preservation, including their original binding, vellum in some instances.

A large number of these rare book treasures were purchased in Europe in 1811 by Ferdinand Rudolph Hassler, the Swiss scientist who was the first superintendent of the Coast Survey (now Coast and Geodetic Survey), which had its inception in 1807 during the administration of President Thomas Jefferson. Some of these books have indorsed on the blank leaves preceding the title-pages, in the handwriting of Hassler, "Library for the survey of the coast," which at that time included only the Atlantic coast of the United States, approximately 1,658 statute miles in extent. The duty of performing hydrographic surveys, conducted for the purpose of making water navigation safe for humanity, its sustenance and wealth, greatly expedited through mod-

ILLUSTRATION OCCURRING OPPOSITE PAGE 498, VOL. II, COOK'S VOYAGES AROUND THE WORLD, LONDON 1790.[1]

[1] The author is under obligations to the U. S. Coast and Geodetic Survey for the illustrations in this article.



DRAWING OF TOPOGRAPHICAL SYMBOLS

OCCURRING OPPOSITE PAGE 54 OF LA SCIENCE DE L'ARPENTEUR BY DUPAIN DE MONTESSON, PARIS 1775.

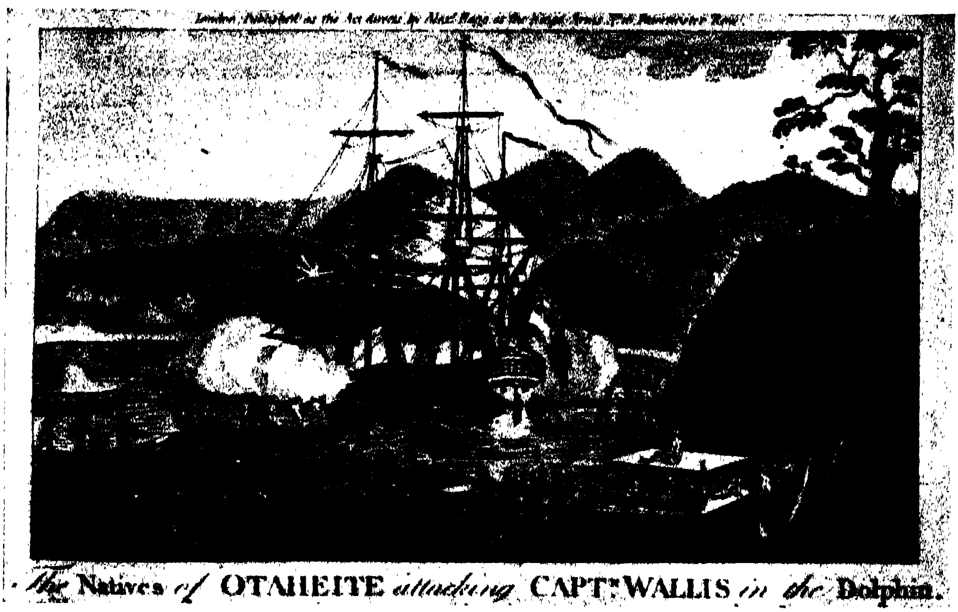


ILLUSTRATION OCCURRING OPPOSITE PAGE 986, VOL. III, COOK'S VOYAGES AROUND THE WORLD, LONDON 1790.

ern development of radio acoustic ranging, now applies to the entire continental and insular shore-line of the United States, 103,000 statute miles.

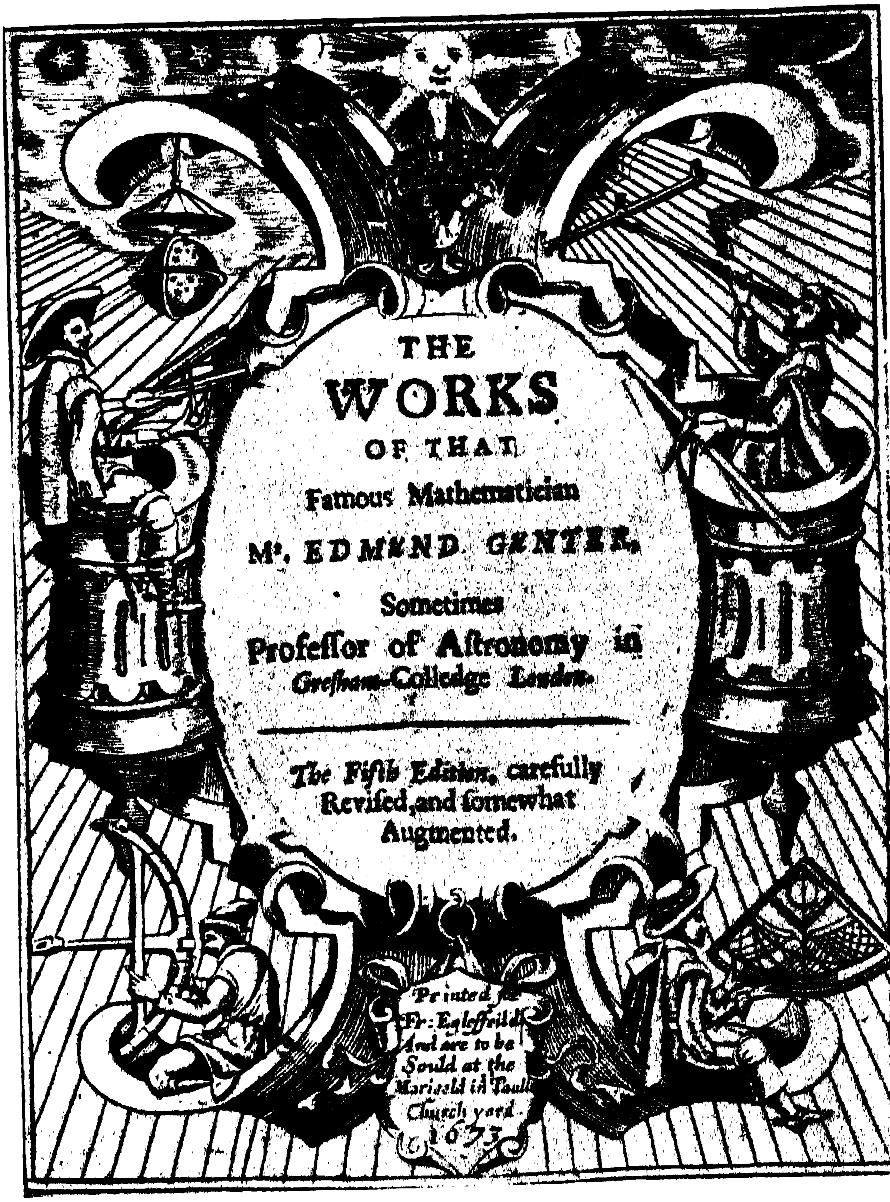
Of the original works purchased by Hassler, he said in part:

When in 1811, F. R. H. was sent to Europe for the procuring of instruments and books for the Government, finding it proper on his part to use the public funds entrusted to him only for the greater objects of immediate want for the coast survey work, he bought on the Government's account only the closest needed books of those times. The books consisted of the best works on astronomy and geodesy, particularly useful for the instruction of the young officers intended to be employed in the work.

Many of these old volumes are profusely illustrated with practical delineations of the use of instruments for observation and surveying, graphic solutions of problems and the composite embellishment of title pages. Quaint designs in direct conjunction with the first letter of an initial paragraph of a chapter are interspersed through these works. A representative selection of these illustrations, photographed from the original, reproduced with this text, afford an idea of their ornateness.

Noteworthy among the astronomical works are three editions of the "Magnae Constructionis Mathematicae," opus of Claude Ptolemy, the Egyptian astronomer, whose great work has remained known by the superlative hybrid name "Almagest," so designated when it was first translated into Arabic A. D. 827 for the astronomer Caliph al-Mamun. The 1528 edition of this work was the first Latin translation made from the Greek first edition of 1451. The following translation of the title page of this copy shows the effusive encomium employed and the prohibition of printing by any other printer, which practice was the forerunner of our present day copyright law:

The Almagest, or the surely divine work of Claude Ptolemy of Alexandria, to wit, his great mathematical compendium of astronomy pre-



TITLE-PAGE OF THE FIFTH EDITION OF THE WORKS OF EDMUND GUNTER, LONDON 1673.

FRONTISPIECE TO TRAITE DES PRATIQUES GEOMETRALES ET PERSPECTIVES, ENSEIGNEES DANS L'ACADEMIE ROYALE DE LA PEINTURE ET SCULPTURE, PAR ABRAHAM BOSSE, PARIS 1665.

sented to the reader in the Latin tongue by the most learned George of Trebizond. Revised by Luke Gauricus of Naples, famous professor of celestial learning in the fostering city of Venice, mistress of the world, in the current year of our salvation 1528. In accordance with a decree of the Senate of Venice let no other printer in Venice or elsewhere in the dominions of Venice print the Almagest within ten years for fear of punishment.

Prominent among the early works printed in English text owned by the technical library of the Coast and Geodetic Survey is an excellently preserved copy of the fifth edition of the famous English mathematician, Edmund Gunter (1581–1626), "sometime professor of astronomy in Greshem-Colledge, London," "printed for Frank Eglesfeild . . . to be sould at the Marigold in St. Paulls Church yard 1673," edited by William Leybourn, who appended after his name "Philomath," indicating that he, too, was a lover of learning. The dedicatory epistle of this edition by Leybourn, addressed to "the right honourable John, Earl of Bridgewater, Viscount Brackley, Baron Ellesmore: one of the lords of His Majesties most honourable privie Council and Lord Lieutenant of the County of Buckingham," begins with highest praise for the works of the learned Gunter.

To-day Gunter, the Hertfordshire mathematician, is still revered by men of science for his scientific contributions and inventions, listed under his name in the fourteenth edition of the Encyclopaedia Britannica, of which the following are cited in part:

With Gunter's name are associated several useful inventions, descriptions of which are given in his treatises on the Sector, Cross-staff, Bow, Quadrant and other Instruments. In 1620 he published his Canon triangulorum. There is reason to believe that Gunter was the first to discover (in 1622 or 1625) that the magnetic declination at one place varies (see Terrestrial Magnetism). He introduced the words cosine and Cotangent (see Trigonometry), and he suggested to Henry Briggs, his friend and colleague, the use of the arithmetical complement (see Briggs' Arithmetica Logarithmica, cap. xv., and Logarithms).

His practical inventions are Gunter's Chain, the chain in common use for surveying, 22 yd. long and divided into 100 links;

Gunter's Line, a logarithmic line, the forerunner of the slide rule;

Gunter's Quadrant, used to find the hour of the day, the sun's azimuth, etc., and also to take the altitude of an object in degrees: and

Gunter's Scale (generally called by seamen the *Gunter*), a large plane scale, engraved with various lines of numbers and used to solve problems in navigation, trigonometry, etc., with the aid of a pair of compasses.

Of probable interest is the quaint advertisement quoted hereafter from the fifth edition of the "Works of Edmund Gunter," which, though not accompanied by any attractive design, was perhaps just as effective for those times as is the multiplicity of modern advertisements:

Whereas the whole subject of the following Treatises do contain the use of Instruments, and that the true and exact making of them is principally to be minded and enquired into, I thought good to give notice, That if any Gentlemen studious in the Mathematicks have or shall have occasion for any Instrument belonging to this Book, as also with all others useful both for Sea and Land, they may be furnished either in Silver, Brass, or Wood, by Walter Hayes, at the Cross-daggers in Moor-fields, next door to the Pope's-head Tavern; where they may have all sorts of Maps, Globes, Sea-plats, Carpenters Rules, Post and Pocket-Dials for any Latitude, &c.

The illustration reproduced elsewhere in this paper headed, "Le Spectacle de la Campagne" (the appearance of the country), from the book, "La Science de L'Arpenteur" (the science of surveying), by M. Dupain De Montesson, Paris, 1765, indicates an authentic source for the comparison of the earlier delineation representing the prominent terrain features with many of the modern related symbols employed in the production of topographical and tactical maps. In some instances the comparison discloses that many of the modern symbols of configurations are similar to

PORTRAIT OF M. DANIEL SCHWENTER,

NUREMBERG LINGUIST AND MATHEMATICIAN, AT 38, BY THE ARTIST APPELES, OCCURRING OPPOSITE PAGE 1 OF TRACTUS II, GEOMETRIAE PRACTICAE NOVAE ET AUCTAE, · 1641. (ORIGINAL VELLUM BINDING).

FRONTISPIECE TO DE ARITHMETICAE ET TRIGONOMETRIA ET GEOMETRIA, BY ADRIANUS METIUS, LEYDEN 1626.

(THE U. S. COAST AND GEODETIC SURVEY COPY IN ORIGINAL VELLUM CONTAINS THE FOLLOWING NOTE: "FROM THE LIBRARY OF THE ANCIENT AND NOBLE FAMILY OF FAIRFAX, COMPRISING THE MANUSCRIPTS OF THE FAMILY AND THE CORRESPONDENCE OF SIR THOMAS FAIRFAX, PARLIAMENTARY GENERAL DURING THE CIVIL WARS, AND AUTOGRAPH LETTERS OF OLIVER CROMWELL AND THE GREAT LEADERS OF HIS TIME. PAPERS OF HIS SON-IN-LAW, GEORGE VILLIERS, DUKE OF BUCKINGHAM, AND UNPUBLISHED COMPUTATIONS OF THE FIRST LORD SIR THOMAS FAIRFAX AND OTHER EMINENT PERSONS OF THE NAME WERE COLLECTED IN THE ANCIENT LIBRARY OF LEEDS CASTLE.")

those used during the early part of the eighteenth century. Others show features that closely resemble those occurring in many of the present-day aerial photographs. In fact, it is not difficult to visualize that the earlier etched symbols appear as though they might have been copied from some recent aerial photographs.

Illustrative of this is an incident where library employees at first glance mistook for an aerial photograph a bromide copy of a map of "Afbeeldinge van de Stadt Amsterdam in Nieuw Neederlandt" (drawing of the City of Amsterdam in New Netherlands), drawn in 1665 by Jacques Cortelyou. This map was precisely drawn as though the artist were looking down on the scene at an angle of 60 degrees. This copy was sent to the late Colonel E. Lester Jones when Director of the Coast and Geodetic Survey, by Comte Cosimo Rucellai, former minister of instruction, Florence, Italy, as a result of their meeting during the session of the International Geographical Union held at Cambridge, England, from July 17 to 25, 1928.

This particular map is included as Plate 82 in Volume II of the "Iconography of Manhattan Island," 1498–1909, by J. N. Phelps Stokes; published by Robert H. Dodd, 1915.

In litigation involving property and riparian rights, early Coast and Geodetic Survey maps of areas of the coastline involved are referred to in court proceedings in cases sometimes involving several million dollars, as an authentic source for the adjudication of such cases. These early maps in turn must necessarily have an authority to fall back on, particularly with reference to the various topographical symbols employed. Therefore, it can be readily understood that the aforementioned group of topographical symbols entitled, "Le Spectacle de la Campagne," is recognized as an authoritative source. As a case in point, some question arises concerning a stretch of land extending from the mainland, narrow for some extent and then expanding to a shape of land indicative of the fact that this stretch of land appears to be an island with the exception of the narrow connection between it and the mainland. The adduced facts disclose that at one time this stretch of land near the shore was a marsh covered by water at high tide, and that by reason of its being filled in by the city the semblance of an island at high tide has been subsequently eliminated. The tiny topographic symbols on early maps indicating the existing condition of the terrain at that time can be resorted to to prove that this stretch of land was at one time an island connected with the mainland by a marshy area.

Every precaution is taken to preserve these rare volumes against too rapid disintegration brought about by the ravages and vicissitudes of climate, time and usage. Consultation by scientists and serious students of these rarities is permitted in the library.

THE PURPOSE OF TIDE OBSERVATIONS

By H. A. MARMER
U. S. COAST AND GEODETIC SURVEY

OUR federal government, through various of its agencies, is engaged in a great variety of technical and scientific activities. The purpose of many of these is clearly apparent from their names. Investigations for the control of hog cholera, studies on the propagation of food fishes, forest research, testing of structural materials—the intent of these is defined by their designations.

The purposes of other technical and scientific activities, however, are not so clearly evident from their names. The government is engaged in making tide observations. What is the purpose of these? To be sure, the tide is an interesting phenomena and has engaged the attention of philosophers and scientists for many centuries. But this scientific interest, obviously, is not sufficient reason for the government assuming the study of tides.

Tidal investigation in this country arose almost wholly in pursuance of aims of a practical nature. In 1807 the Coast Survey was established for the purpose of charting the coast. Immediately the need for tide observations became apparent. For the boundary between land and sea shifts continually—landward with the rising tide and seaward with the falling tide. Furthermore, the heights attained by high water and low water at any place vary from day to day. In fixing the boundary between land and sea these tidal features must clearly be taken into account.

Again, in determining the depths of the water in the region covered by a chart, depth measurements, or soundings as they are usually called, are made. But these depths, as actually measured, do not correctly represent the depths in the region; for the soundings are made from the surface of the sea, the level of which is constantly changing under the influence of the rise and fall of the tide, and of the disturbing effects of wind and weather. To determine the correct depths from the soundings they must be reduced to some uniform level or fixed datum plane.

Begun thus as an incidental detail in connection with its hydrographic and geodetic surveying, the tidal work of the Coast and Geodetic Survey has gradually expanded in scope and assumed larger proportions. This expansion became necessary both in meeting the various problems arising from its own primary surveying operations, and in meeting the demands made by other governmental agencies and by the public generally. Quite apart from the closely related work dealing with tidal currents, the purposes now served by the tidal work of this bureau may be classed under five heads as follows: (a) determination of datum planes; (b) establishment of tidal bench marks; (c) publication of tide tables; (d) maintenance of records of rise and fall of tide; (e) study of tides and tidal phenomena. What is comprised under each of these five heads is described briefly below.

DATUM PLANES

The necessity for datum planes in connection with harbor and coast charts has already been mentioned. As a rule some low water plane such as mean low water, mean lower low water, or low water springs is adopted for such charts, and such datums can be determined only by means of tide observations.

For charting depths in the sea, and more specially in coastal waters, the

necessity for a tidal datum plane is clear; but for reckoning heights on land it would appear at first thought as if the tides were wholly out of consideration. And for a time heights on land were reckoned from local arbitrary datums, this procedure involving no difficulties, so long as the country was sparsely settled and communities isolated. However, when lines of levels carried from such arbitrary datums met, confusion was inevitable. And this confusion became compounded with the expansion of the country and with the growth of large urban centers.

A further difficulty in connection with the use of arbitrary datum planes for reckoning heights on land arises when it becomes necessary to recover such datum planes. If the point originally chosen as defining the datum is changed or destroyed it frequently becomes impossible to recover the datum used, and surveys based on such datums can not be correlated.

The desirability of a uniform datum for reckoning heights on land is obvious. Such a datum should possess the further advantage of certainty of recovery, even though all bench mark connections be lost. These advantages are furnished by the datum of mean sea level. Heights on land, whether along the coast or in the interior of the country are now reckoned from mean sea level. All civilized nations are spreading lines of precise levels throughout the territories under their jurisdiction for the purpose of making this datum available in all sections of the country. And like the low water datums used in harbor and coast charts, the datum of mean sea level can be determined only by means of tide observations. From the coast, where this datum is established by the tide observations, the engineer carries it throughout the land by means of spirit levels.

For other purposes other datum planes are used. In connection with the development of lands fronting the seashore, the datum of high water is of importance. And at certain places distinction must be made between the datums of mean high water, higher high water, and storm high water. All such datum planes, too, can be determined only by means of tide observations.

In connection with datum planes that may be used as planes of reference, both for heights on land and depths in the sea, it is to be noted that those based on the rise and fall of the tide possess the advantages of simplicity of definition, accuracy of determination, readiness of correlation, and certainty of recovery even though all bench mark connections be lost. It is for these reasons that datum planes defined by the tide are used in engineering and in other technical and scientific work.

If the rise and fall of the tide were exactly the same from day to day, the determination of a tidal datum plane would be a very simple matter. Any low water would determine mean low water, any high water mean high water, and one day of observations would determine mean sea level. But high water, low water, and sea level vary from day to day, from month to month, and from year to year. It was therefore necessary to study the fluctuations to which the tide is subject in order that accurate datum planes might be derived.

It was found that the primary fluctuations of the tide go through a cycle of about nineteen years. In other words, to determine accurately the tidal datum planes at any place requires nineteen years of observations. But this is a very considerable period of time; and if nineteen years of observations were necessary to derive the datum planes at all places where these are required, the practical problem would be a very formidable one. Could not methods be devised by means of which the results from short series of observations might be reduced to mean values? Further study of the tide proved that this could be done, and now

datum planes may be determined with considerable precision from observations covering a year of observations or even less.

Bench Marks

From the tide observations made at any point, the various datum planes are determined as corresponding to certain heights on a fixed tide staff used in making the observations at that point. In other words, these datum planes at that point are specified as so many feet and hundredths above the zero of a given tide staff. And if it were a simple matter to maintain that tide staff for many years without change in elevation, it would serve very well for preserving the determination of the different datum planes.

But unfortunately it is very rare that a tide staff remains undisturbed for a number of years. Deterioration of the material of which it is made, changes in wharves and piling, and accidents of one kind or another are certain to occur. And unless some means are used for preserving the datum planes determined by a given series of observations, these would be lost in the course of time. It is this purpose that tidal bench marks serve.

Tidal bench marks, established in rock or concrete, or on some substantial structure, preserve the datum planes derived from a series of tide observations. By connecting these bench marks, by means of spirit levels, with the zero of the tide staff, the relation of the various datum planes to the bench marks becomes known. A number of bench marks are established in connection with the tide observations in a given locality so that even if several are destroyed with the passing years, others will remain. With this thought in mind, too, the bench marks are scattered to insure against loss from a common cause.

At hundreds of places along the coasts of the United States, bench marks have been established. The descriptions and elevations of these are being published in pamphlets which are available to the engineer, the geologist and others interested. From time to time, as opportunity affords, these bench marks are inspected and releveled, and new ones established to take the place of any that have become displaced or destroyed.

Tide Tables

On the charts which the mariner makes use of in navigating his ship, the depths shown refer to some fixed low water datum. But the depths he will actually find at any given time depend on the state of the tide. With the shallow-draught sailing vessels of an earlier generation there was generally a sufficient depth of water in most harbors and important channels at all stages of the tide, and the navigator therefore troubled himself but little in regard to the state of the tide.

Now, however, with the deep-draught vessels of modern commerce approaching the depth of the water over bars and in channels leading to important ports, the state of the tide becomes a matter of vital importance. The cost of operation of a modern vessel and the exacting schedules to which modern shipping is subject make it a serious matter for a vessel to lie several hours outside a harbor awaiting a favorable tide. The navigator, whether of a merchantman or of a man-of-war, now must have advance information in regard to the state of the tide in the regions which his vessel is to traverse.

This advance knowledge of the state of the tide is furnished the navigator through tide tables which give predictions of the times and heights of the high and low waters for each day of a year at the most important harbors. Each of the leading maritime nations issues tide tables, and for the United States this

work devolves on the Coast and Geodetic Survey. Early in the summer of each year this bureau issues a volume of some 400 pages which foretells for every day of the following year the times and heights of each high and low water at 94 of the principal ports of the world. In addition, data are given for more than 3,000 other places, which in connection with the daily predictions for the 94 principal ports, permit the navigator to predict the tides also for these places.

If the tide were the simple phenomenon that one might be led to infer from the treatment of the subject in our textbooks on astronomy or physical geography, the prediction of tides would be a simple matter. Indeed, in the earlier tide tables, which were restricted to ports on the Atlantic Ocean, the predictions were made by very simple methods, since the tides in this ocean are relatively simple tides. But when it was found necessary to extend these tide tables to cover ports in the other oceans, difficulties were encountered. Not only do the times and heights of the tides at different places differ, but the very character of the rise and fall of the tide is found to exhibit almost bewildering variety.

In the Atlantic Ocean there are at most places two high waters and two low waters in a tidal day of 24 hours and 50 minutes. Furthermore, morning and afternoon tides are much the same in height and in other characteristics. And while the times and heights of the tide at these places vary somewhat from day to day in accordance with the changing positions of the moon, these variations are relatively small. In other words, the tides of the Atlantic Ocean are relatively simple tides.

But when we come to predict the tides for Seattle, Washington, it is found that while there are two high waters and two low waters each tidal day, morning and afternoon tides are quite unlike. The two high waters are found to be much alike but the two low waters differ—at times by as much as 8 feet. At Honolulu, on the other hand, the two low waters of each day are much alike, but the two high waters differ. And at San Diego both the high waters and the low waters of each day differ.

This does not exhaust the variety in tides. For at Pensacola, Florida, there is only one high water and one low water each day, while at Galveston, Texas, part of the time one high water and one low water occur in a day, and at other times two high waters and two low waters occur. Similar tides are also found at other places.

That the movement of the tide is in some way intimately connected with the movements of the moon has been known for centuries. This fact finds expression in the colloquial dictum that "the tide follows the moon." As a general statement this is true, but there are places where this relation does not appear to hold. At Tahiti, the tide appears to follow the sun, both in the times of high and low water. And at Jolo, in the Sulu Archipelago of the Philippine Islands, the high waters follow the moon, but the low waters follow the sun.

In solving the practical problems of tide prediction for the different kinds of tides, it was necessary to study tides and tidal phenomena in order to arrive at an understanding of the causes and factors involved. That such study has been successful is evidenced by the fact that methods and instruments have been evolved by means of which the most complicated tide can now be predicted by means of mechanical tide predictors.

Tide Records

In connection with the varied activities of modern life it becomes important at different times to ascertain the state of the tide at some past time. Admiralty cases involving the collision or the grounding of a vessel; cases affecting title to lands fronting on the water, the boundaries of which frequently refer to

high or low water; damage to property during some exceptionally high tide; cases involving changes in the rise and fall of the tide consequent on harbor improvement—all these demand observation data on the rise and fall of the tide. This means that some agency must maintain a file of tidal data which shall be taken as authoritative.

At certain selected points along the coasts and inland tidal waters of the United States, the Coast and Geodetic Survey maintains primary tide stations at which continuous tide observations are being obtained by means of automatic tide gauges. Since the appropriation for the tidal work is limited and the coast line considerable, it is the policy of the bureau to operate as many of these tide stations as possible on a coöperative basis with other governmental, state, or municipal agencies. By this means a uniform standard of precision is maintained in the tide work throughout the country at a minimum of cost.

The tide records from the primary tide stations constitute a primary source of the data on the rise and fall of the tide in their respective localities. By means of these records, too, it is possible to compute with reasonable confidence the state of the tide at other places some distance away. Thus with about thirty primary tide stations along the three coasts of continental United States it is possible to secure observations that cover the country in a fairly satisfactory manner.

The tide records obtained from the primary tide stations serve not only the purposes specified in the first paragraph of this section, but also other purposes as well. The data so obtained are used also in the tidal control for hydrographic work and in correcting to mean values the results from short series of observations. They furnish also the basic data for the study and advancement of the subject of tides and tidal phenomena.

Tides and Tidal Phenomena

As in other fields of technical work, it is virtually impossible in connection with tides and tidal phenomena to draw the line between the technical and the scientific, between the practical and the theoretical. Starting from the practical need of correcting soundings for the rise and fall of the tide, it became necessary to study the whole subject of tides and tidal phenomena in order that the practical purposes which the tide observations serve might be carried out most economically and most efficiently.

Throughout the world, almost without exception, tidal work is carried out by governmental agencies in connection with other public work. As a consequence there is in each country but one small organization engaged in this work. This means that improvements in methods and instruments can not be looked for on the outside; these must come from within the small groups engaged in that work. For this reason it becomes necessary to engage in research not only that the tidal work may keep abreast of the times, but more especially that the demands made by other fields of technical work, which are growing constantly, may be met efficiently. This research in turn necessitates a study of the subject of tides and tidal phenomena in all its phases.

As a branch of pure science, the theory of tides falls within the domains of celestial mechanics and hydrodynamics. And in these abstruse theoretical subjects it is the world's great mathematicians that have led the advance. But in the development of the technical work designed to carry out the practical purposes of tide observations it is the tidal specialist, or the tidal engineer as he is now known, who has had to shoulder the burden.

To carry out these practical purposes he has been compelled to study the whole subject of tides. Why do the tides in

the arm of the sea known as the Gulf of Maine and the Bay of Fundy differ so greatly in height, one foot on Nantucket Island to more than 40 feet at the head of the Bay of Fundy? Why are the tides in the Atlantic so much simpler than in the Pacific and Indian Oceans? Why are the tides at the two ends of the Panama Canal so strikingly different? As the crow flies, the ends of this canal are but little more than thirty nautical miles apart, yet at the Atlantic entrance the rise and fall is less than a foot on the average, while at the Pacific end the rise and fall averages more than 12 feet. Why the peculiar behavior of the tide at Tahiti, where it appears to follow the sun rather than the moon? Why one high and low water in a day at one place and two high and low waters at another?

These are but a few illustrative examples of a great variety of questions with which the tidal specialist is confronted. Altogether aside from their scientific importance, which could not but help enlist the interest of the trained worker, the necessity for solving the practical problems involved compelled research. As a result, the tidal specialists in government employ have a very considerable body of scientific research in tides to their credit.

The different purposes for which the tidal work of the Coast and Geodetic Survey is carried on are obviously not mutually exclusive. Indeed, they fit in so well with each other that operations carried on for one purpose at the same time serve the other purposes. At the basis of all tidal work and research, however, lie the field observations on the rise and fall of the tide.

Some Collateral Uses of Tide Observations

The purposes described above are the primary purposes for which tide observations are being made by the federal government. The data derived from these observations, however, lend themselves to other purposes of a less immediately practical nature. Take the question of coastal stability. For a number of years it has been taken for granted that the Atlantic coast of the United States is subsiding at the rate of about two feet per century. The evidence upon which this conclusion was based was of various kinds. Indian shell heaps are now found below high tide level; tree stumps are found in place in salt marshes, indicating that the trees were killed by the invasion of salt water; salt-water marshes appear to have encroached upon the upland areas. These and similar facts are taken to indicate a gradual subsidence of the Atlantic coast of the United States.

This evidence, however, is not at all conclusive. Certain competent students of the problem regard the facts cited as capable of interpretation in other ways, without invoking a subsidence of the coast. But if there were at hand systematic tide observations for the past century, the question could be answered conclusively. For if the coast were subsiding, sealevel would now stand higher than formerly. Unfortunately, the earlier tide observations were made for purposes of an immediately practical nature, and do not lend themselves to study for this purpose. But with the continuance of the systematic observations now in progress, the data will furnish conclusive evidence in regard to coastal stability, a question obviously of very great importance.

On the open coast the tide is an agent of geologic change. The coast line, as the term is ordinarily used, is supposed to mark the boundary between land and sea, and on the small scale maps which are generally used it has a deceptive appearance of precise location. In reality, however, the term is a misnomer, for land and sea meet, not in a line, but in a zone marked by shifting boundaries

of varying width. This zone belongs now to the sea and now to the land. At low water the land extends farther seaward and at high water the sea encroaches on the land. At times of neap tides the width of this zone is much reduced, while at times of spring tides it has its greatest width. This zone is frequently called the foreshore.

Now the foreshore is the scene of constant warfare and change. Here wave and current have their greatest effect in their attack on the land. At one point the land gives way slowly to the sea under the constant beat of the waves; at another point the turbid waters are relieved of their load of sediment to form a bar or spit which the land finally redeems from the sea. The tide thus enters as a factor of geologic change along the coast. And in the study of shore-line changes, tide observations furnish the data necessary in evaluating the share of the tide.

Along the coast and in inland bodies of tidal water, the biologist must reckon with the tide in the problems that confront him. For to the plant and animal life in tidal waters the distribution of temperature and salinity is of great importance. And in this distribution, the tide plays an important part in the constant interchange which it effects between the coastal waters and the waters of the open sea. In this field of investigation, too, tide observations furnish basic data.

Going farther afield it is found that the tide enters into a great variety of problems as a factor that can not be neglected. Many of these problems appear at first glance to have nothing to do with the tide. Such questions as the rigidity of the earth, the apparent secular variation of the moon, the change in the rotational velocity of the earth—questions which clearly fall within the domain of the geophysicist, the astronomer and the cosmogonist, and appear to be far removed from tides. Yet in the investigations of these matters various facts are encountered which can be interpreted only through a study of the tide.

An enumeration of all the fields of investigation into which tides enter as important factors would make a long list—altogether too long for the present article. All that is intended here is to direct attention to the primary purposes for which tide observations are being made, and to point out that in serving these purposes they lend themselves also to investigations in other fields. It must be emphasized, however, that to secure full value from such observations they must be made systematically and continuously. Fortunately such observations can be secured at very little cost by the use of automatic tide gauges.

THE CRIME OF ARCHEOLOGY—A STUDY OF WEATHERING

By Professor HERDMAN F. CLELAND
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Introduction

The observations and conclusions in this paper are the result of brief visits to some of the more important sites of Greek and Roman antiquity during the summer of 1931. As a geologist, the writer was especially interested in the effects of the weather on ancient buildings, sculptures, and carvings, and it is to the disintegration of ancient art by this agency that attention will be called.

Anyone who has even an elementary knowledge of the art and architecture of ancient Greece and Rome and of older or contemporary peoples who have directly or indirectly contributed to the development of these great civilizations will appreciate the desirability of preserving for all time as much as possible of what remains of the works of these ancients.

Most archeologists in their desire to display their discoveries to the world fail to realize that exposure to the weather soon utterly destroys the works of man. They also fail to take into account the fact that, in general, destruction takes place at an increasingly rapid rate as checks and cracks are opened in weathering, so that a column, for example, which may show little evidence of weathering at the end of a hundred years may be greatly disintegrated at the end of a second century.

The archeologist does not seem to appreciate fully that in his desire to show his contemporaries what he has discovered, he is compelling future generations to depend, more and more with the years, upon written descriptions and illustrations for their knowledge of the works of antiquity.

Typical Examples of the Effect of Agents of the Weather

Striking and distressing examples of this thoughtlessness of archeologists can be seen in many places in the Mediterranean Basin. At Cnossus, for example, the thin slabs of coarsely crystalline gypsum which were cut by the ancient Minoans and used as wainscotings and pavements have been cleared of débris, and, already, many of them have been warped and broken. In a generation or two they will be reduced to sand and will be recognized as slabs with great difficulty.

The effect of the exposure of mosaics and frescoes to the blistering heat of the sun, the cool of the night and to soaking rains is already apparent in many excavations in the Mediterranean Basin. It has been observed that the mosaics of Delos are faded after a few years' exposure to the sun. At Carthage not only are the mosaics exposed to the sun, but some of them are the stamping grounds for herds of goats.

The floor of one of the basilicas in the Forum at Rome contains the remains of copper coins which adhere to the surface as a result of the heat of a fire which destroyed the building. The only protection given to these objects are a few loose boards, which are moved by the guide when he shows the pavement to visitors.

When Delphi was excavated the archeologists did a splendid piece of work, judged by their standards. They uncovered every column, every inscription, every carving and foundation stone that nature had so carefully preserved. Everything, in fact, is exposed, and the

destructive work of the weather is at a maximum. The interesting notices in small Greek characters which tell of the freeing of slaves are in walls where they must inevitably rapidly become illegible.

Although the Temple of Apollo at Delphi was finally restored at the beginning of the third century of our era, almost nothing remains *in situ* but fragments of pavements and the foundation stones. This destruction was brought about largely by the weather, assisted, possibly, by earthquake shocks.

In 1918, an underground basilica of the second century of our era was accidentally discovered in Rome. When first opened to the public, the monument was most spectacular with the entire surface of its vaults, walls and piers covered with pure white stucco reliefs which glistened in the artificial light. Now, less than fifteen years after its discovery, the monument is almost a wreck. Moisture has seeped through and has discolored the stucco and has loosened it so that, already, large patches have fallen off. In a few years, what was once a superb example of the stucco worker's art will be a complete ruin.

In Great Britain where the effects of the weather on stone should be apparent to every one; where it is said, that the building stones of the exterior of Westminster Abbey have been replaced five times, and where many of the stones of the comparatively new Parliament Buildings are already badly weathered, even here one finds ancient carvings and fragments of statuary exposed to the elements in churchyards. The same disregard of the inevitable effects of the weather is everywhere apparent in France and nearly every other country in Europe and the Americas. A study of the modern statuary in the Tuilleries garden in Paris will convince any one of the destructive work of the weather within a few generations in that city.

When, in 1811, Lord Elgin disregarded the right of the Greeks to their own works of art, and removed the statues of the pediments of the Parthenon to England, he was justly criticized for his lack of ethics. But, if these superb works of art had not been protected from the weather, as they have been in the British Museum, they would now be so badly weathered that little if any of their beauty would have remained.

The excavations at Delos by the French have uncovered many interesting things: mosaics, columns, foundations, statuary, stucco and painted wall decorations. Only a few people visit this ancient shrine of Apollo each year. Nevertheless, mosaics, columns, carvings, stucco and painted walls are left to the mercies of relentless forces which are rapidly destroying them.

The only protection of the thirty-five century old hearth of Agamemnon at Mycenae is a thin layer of earth which can be scraped off with the toe of the shoe.

Ancient Troy will not have suffered greatly from the work of the archeologist because, on account of its situation on the edge of a plateau overlooking the fertile plain of Troy, wind-borne sand and soil is rapidly filling in the excavations where it is being held by a luxuriant growth of thorny plants.

Mussolini, in his laudable ambition to make of Italy the most interesting and desirable spot in the world, has spent great sums of money in excavating and restoring ancient monuments and buildings. Noble as this purpose is, the result will be the eventual total destruction of these works of antiquity. A typical example of what may be expected is to be seen in the work which was done at Hadrian's Villa shortly before Mussolini came into power. Some walls were restored, and mosaics and marble inlaid floors were uncovered. Everything possible was done to make it interesting to the people of the present.

If this policy is continued for many

years, restoration will follow restoration until the history of Hadrian's Villa and other Roman ruins will be somewhat like that of Benjamin Franklin's famous cider barrel. According to the story, when the original heads of the barrel rotted away, they were replaced by new ones. When the staves rotted or broke, they were replaced one by one. At last, the only part of the original barrel which remained was the bung hole.

The Instructive Story of Olympia

Nature both destroys and preserves. If it had not been for an earthquake, landslides which dammed a river, and the flooding which resulted from the breaking of this barrier, little would have been left of the remains of ancient Olympia. The history of this center, which for more than a thousand years was the national center of Greek religion and the scene of the greatest athletic festival the world has ever known, is in brief as follows:

The first Olympiad is usually placed at 776 B. C., and the games were celebrated at intervals of four years until 393 A. D. In 394 A. D. they were abolished, and in 426 the destruction of all pagan temples was decreed. For nearly or quite a hundred years the temples, from time to time, were plundered of their marble columns and statuary, and easily removable fragments of marble were burned for lime, as is shown by the discovery of an unburnt charge in a limekiln which contained the heads, arms and legs of ancient statues.

In 522 and 551 A. D. the Peloponnesus was shaken by earthquakes. One or both of these shocks overthrew the temple of Zeus, and the great drums of the columns of the temple now look like piles of gigantic checkers which had toppled over. During the second of these earthquakes, great masses of land slid from the sides of the steep hills into the valley of the Kladeos River, forming a dam. The pressure of the rising water behind this dam eventually became so great that it burst through this barrier, carried great quantities of sediment and spread it over the western part of the temple area. Later, other floods deposited more sand and gravel until the temple area was buried in places to a depth of twenty feet. Then, for more than a thousand years, the foundations, the lower parts of the walls and the overthrown columns were comparatively safe from the destroying hand of man and nature. Not entirely safe because it was used as a quarry by the Turks and later inhabitants. For example, in 1766, "the walls of the cella of a great temple standing many feet high" was reported, but thirty-nine years later the walls were said to be only two feet above the ground.

The first archeological excavation was carried on in 1829, but it was not until 1876 that the careful work of the German archeologists had brought to light the foundations and walls of the temples as we see them to-day. The great volume of sand and gravel which covered the Altis or Temple Area was carted to the river, which in turn transported it to the sea.

The archeologist's work at Olympia is nearly done. He has measured and mapped the ruins. He has removed the more important pieces of statuary and architectural fragments to museums. He has made models and innumerable drawings. He has expounded his theories and has left for posterity a complete and beautifully illustrated description of his labors. The ruins now lie exposed to the weather and are visited by a relatively few people each year, only a few of whom "know what it is all about." The River Kladeos may again come to the rescue and conceal the remnants of the temples with a protecting cover of sediment so that future generations of scholars may again excavate and have the pleasure and profit of seeing the actual architecture of ancient Greece.

If, however, the ruins are left uncovered, column, wall and foundation will gradually disintegrate, just as has the gleaming white temple of Poseidon on beautiful Cape Colonna. The destruction will not be as rapid as in the latter, which is "melting away" so speedily that a visitor after an absence of five or six years is painfully aware of the disintegration which took place in that brief interval, but it will as surely disappear.

Suggestions and Comments

If the assumption of the writer is true that works of antiquity should be preserved for students of the distant future, that students of to-day should not deprive men and women who are to live after them of the privilege of seeing and studying the objects which ancient man made, it is obvious that archeologists should hesitate to undertake more excavations unless they can be reasonably certain that the objects they uncover can be preserved for people of the very distant future.

Objects in Museums

It is generally assumed that an object placed in a museum or under shelter is safe from disintegration. A study of objects now in museums and other buildings will show that not only wood but even stone and bronze may decay. A striking example is that of the so-called Purbeck Marble used in the Richard Beauchamp monument in St. Mary's Church, Warwick, England, and in several other English churches. The fossils which constitute a large part of the stone have loosened and fallen out to such a degree that the stone is nearly ready to fall apart.

Another similar object lesson is to be seen in the New York State Capitol, at Albany, in which some of the many narrow marble slabs in one of the halls are already showing signs of decay. Curators of museums are fully aware of the decay of objects under their care.

The Desirability of Refilling Excavated Sites

Attention has been called to the destruction—some rapid, some slow—of objects exposed to the weather. Every archeologist must be aware of the fact that in a few centuries the carvings, flutings and even the form of column and cornice will have wasted away, if they are left as they are now. This being true, should they say in effect: "This is an unfortunate circumstance but it was necessary if the world was to learn of these things." The correct answer seems obvious. If an excavation is to be made, as, for example, the new excavations of the American School of Classical Studies at Athens in the Agora, arrangements should be made in advance of the excavations to refill the excavations as soon as all that can be learned from them is obtained. Any statuary or other work of art should not be removed unless it is probable that these objects will be kept in their present condition for a thousand years.

The refilling of excavations should, however, not be begun until it has been learned what kind of a cover will best preserve the archeological remains. For example, if the Hermes of Praxiteles at Olympia had not fallen face downward in soft mud, but instead had been buried in gravel, its beauty would have disappeared. The texture of the surface which is the marvel of sculptors would have been obliterated by the solvent power of ground water.

The archeological history of Pompeii and Herculaneum shows the importance of a suitable cover. Pompeii was buried beneath thick beds of porous volcanic ash. Because of the porous character of the deposit, underground water carrying oxygen and carbon dioxide could readily circulate. One effect has been the rotting away and disappearance of wooden objects. Seldom is any uncharred wood preserved. Herculaneum was buried under a relatively impervi-

ous volcanic mud, which prevented the circulation of water. As a result of the absence of daily changes of temperature and of the circulation of ground water, organic objects are much better preserved.

The Necessity of Scientific Research for Stone Preservatives

Whether or not archeologists agree with the above suggestion, they will concede that Greek and Roman antiquities should be preserved if such can be accomplished without depriving the scholars of to-day of the pleasure and profit of studying them. Therefore, one of the most obvious needs of archeology is preservatives with which to treat stone objects so that they will not crumble and dissolve. Without stone preservatives the excellent and costly restorations of Mayan temples which are now being constructed in Yucatan will have a short life.

The writer feels that immediate steps should be taken to provide a fund for the encouragement of scientific research along these lines. The knowledge derived from such studies would be of value not only to the archeologist but also to architects who plan buildings which, they hope, will endure for centuries. Such investigation would probably be expensive and might require several years of experimentation, but it is imperative if existing remains are to be saved.

Summary

A few of the many striking examples of the destruction by the weather of works of antiquity have been pointed out. Two suggestions for the preservation of archeological finds are offered. The first is to re-bury excavations after they have been thoroughly studied; the second is that scientists be encouraged to search for some means by which objects exposed to the weather can be kept from disintegration.

Until some method is discovered for preventing the decay of works of antiquity, excavations should be limited. In this connection it is interesting to note that improved archeological methods are being discovered. It will be recalled that, in the older excavations of Pompeii, trenches were dug and the digging proceeded from the side of a building inward. In the new excavations the digging is from the surface downward. In this way when a cavity such as that left by the entire decay of the wood of a door is encountered, plaster is poured into the cavity and a cast of the wooden object is obtained. This is well shown in the house of Menander, where a cast of a wooden door with a broken bronze bar is propped up with a cast of a log of wood. With the methods formerly in use such discoveries were improbable. The fact that archeological methods are improving should cause archeologists to hesitate to make any but the most necessary excavations.

Some scholars will probably feel that the men of the present need have no thought for the people of a thousand years hence; that some new political disease or government may have caused the Parthenon and the Coliseum to be torn down for building stones or because of a passing fancy that a knowledge of the past should be obliterated. Perhaps some will go so far as to say that we are now enjoying the warmth of an interglacial period which will be followed by refrigeration, and that the future is too uncertain to be considered.

Assuming that conditions remain as they now are for some thousands of years, and that the human race will not deteriorate during that time, failure to protect the monuments of antiquity for future scholars will make appropriate the sarcastic remark of Job: "No doubt but ye are the people and wisdom shall die with you."

SCIENCE SERVICE RADIO TALKS

PRESENTED OVER THE COLUMBIA BROADCASTING SYSTEM

THE UNITED STATES DURING THE ICE AGE

By Professor J HARLEN BRETZ

UNIVERSITY OF CHICAGO

So you think the climate must be changing? We surely have been having unusual weather for the past few seasons. A drought without precedent, a summer hot beyond all records, winters so mild in the East and Mid-West that Florida and California lose almost all their charm. The memory of the oldest inhabitant is hard-pressed to match these recent extremes. But weather in this latitude is always surprising us; one reason why it's always a satisfactory beginning for any conversation. And what you perhaps thought was climatic change has been only weather variability. Since climate is the average of the weather over a long period of time, it is obvious that climatic change must be extremely slow. Our Weather Bureau should be allowed to collect figures on rainfall, snowfall, temperature, winds, etc., for a hundred years yet before we press them with the question "Is our climate changing?"

What about records of climatic changes before the weather man began making his records? We have them. Geologists, rather than meteorologists, have supplied us. What do you think about that "Ice Age"? Didn't it require a much colder climate than we now have in Canada and northern United States? "But," you may say, as my granddad always said to me, "that Ice Age stuff is all theory." I never could convince him; he knew no geology and he was "sot" in his ways. He knew what he wanted to believe, and what he didn't want to believe. Can I convince you in the very brief time I have?

Almost everywhere on the land there is a surface cover of soil and subsoil overlying firm bedrock. In most places this soil and subsoil is a product of the decay and disintegration of the bedrock itself. Its boulders are all of the underlying kind of rock, its texture is coarser with increasing depth and it grades imperceptibly into the undecayed bedrock. There is no sharp break between soil and subsoil above and bedrock below. But in the northern part of the United States, the soil and subsoil rest with sharp contact on undecayed bedrock. There are boulders and smaller stones in it of various kinds of rocks, unlike the bedrock itself. In many places the surface of the bedrock, when cleaned off, shows long straight, parallel scratches, running nearly north-south. Boulder surfaces also are scratched and even planed off.

These peculiar features mean that this material, overlying the bedrock of the Northern states, was transported here from some other place, that in the transportation there was a great scouring action, and that the rock fragments which grooved and scratched the underlying rock surface and themselves became grooved and scratched were rigidly held in position and rigidly held on one course. Stream-carried stones do not get scratched this way nor do they make scratches on the rocky stream bed. Waves do not move their pebbles and cobbles in such a way as to make these

markings. The only agent which shifts loose material about on the land surface to produce these markings is glacial ice. Geologists have run around enough and looked at the earth's features enough by this time to be of one opinion on this point. They have studied glaciers in our western mountains, in Alaska, in Greenland, in Antarctica and elsewhere. There is no ground for reasonable doubt. We do have a record, an indisputable one, of notable climatic change in the northern United States.

Under what conditions does glaciation occur to-day? For one thing, most of the precipitation must be in the form of snow. For another thing, the summers must be so short and so cool that not all the winter's snow is melted off. If a residuum of one foot of snow is left after each summer's melting, a century of time should see an accumulation 100 feet deep, that is, if no consolidation of the snow occurs. But perhaps you have seen an old snow drift after a few weeks of day-time melting and night-time refreezing. If so, you know that the last of this snow is a coarse-grained, porous ice, much denser than the original snow when the drift was made. To be a true glacier, this ice-from-snow needs only to be thick enough and to lie on a slope. The strength of ice is relatively slight and its own weight, when sufficiently thick, will deform it. Gravity thus causes it to flow very slowly downgrade, somewhat like a very thick mass of tar.

The scratched bedrock under the glacial deposits of the northern United States shows that the ancient ice sheet of North America moved southward, coming from Canadian territory. Many of the foreign boulders in the deposit ("niggerheads" or "hardheads," my granddad called them) are traceable back along the trail of the bedrock scratches to ledges of granite several hundred miles to the northward. The great ice sheet grew in northern Canada and spread out chiefly to the south. How far into the United States did it get?

The southern limit of this peculiar soil and subsoil of the United States (geologists call it glacial drift) makes an irregular line from New Jersey on the Atlantic coast to the state of Washington on the Pacific. All New England and New York are covered by the glacial drift, and the northern parts of New Jersey and Pennsylvania. Most of Ohio, Indiana and Illinois are covered, only the extreme southern portions escaping. At Cincinnati the ice sheet, recorded by the drift deposit, pushed across the Ohio River about 20 miles into Kentucky. But it reached still farther south in Illinois, there attaining its greatest extent. All the states of the Upper Mississippi Valley and the Great Lakes Region were covered, the ice invading northern Missouri, extreme northeastern Kansas and eastern Nebraska. From here the margin of the drift swings northwestward across the Dakotas and only the northern third of Montana was covered. Across the Rocky Mountains and the Cascade Range the margin is very irregular, as would be expected in a region of great relief. The panhandle of Idaho and the northern third of Washington were covered by Canadian ice.

Such an invasion by glacial ice hundreds of feet thick must have made great changes in river courses in the northern part of our country. Examining the evidence in the field, we have found that the upper part of the Missouri drainage area was formerly tributary to Hudson Bay and the Arctic Ocean, and became shifted over to the Mississippi system and the Gulf of Mexico. Several rivers of western Pennsylvania, now tributary to the Ohio, were formerly confluents of the St. Lawrence system. The Great Lakes, which were river valleys in preglacial time, were modified to become the greatest group of fresh-water lakes in the world.

A climate producing such a prodigious ice sheet (covering nearly half of North America) must have favored local glaciation in the western mountains south of the main sheet of ice. We find records of valley glaciers in the mountains, like those of Glacier Park to-day, in every Western state, the high mountains of Colorado, Wyoming, Oregon and California having the largest development. Shrunken remnants of some of these still exist. Even New Mexico and Arizona had local valley glaciers during the Ice Age. The southernmost record of glacial ice in the United States occurs in southern California, south of the latitude of Los Angeles, though, of course, high up in a group of mountains.

The climatic change which caused the Ice Age was an interruption. Animals and plants living before the glaciation in the northern part of what is now the United States were temperate climate forms, as the fossil record shows. The growth of the ice sheet was enormously slow; so was its advance. Perhaps a mile in twenty years was its speed limit. Generations came and went during the refrigeration, and thus even plants, unable to pick up and walk out, had the opportunity to migrate southward. As the Arctic climate gradually developed, a great wave of sub-Arctic forms slowly moved down into the Northern states and replaced the earlier temperate forms. Many of them finally reached even the Southern states. Not all survived the stress of this migration; many species became extinct. But several animal kinds living to-day in northern North America made the two-thousand mile trip southward, and as the ice finally melted away, moved back again. Walrus bones have been found in Georgia, caribou or reindeer in Pennsylvania and Ohio, moose in Kentucky and Missouri, elk in Florida and Arkansas, and muskoxen (living to-day only in northern Greenland) have been found in Kentucky, Oklahoma and Arkansas. Fossil remains of the tamarack, a typical northern tree, have been reported from Georgia. A very curious consequence of the return of these cold-temperate and subarctic forms when the ice finally melted away is known in the New England mountains. Here at high altitudes live to-day certain Arctic plants and insects, a thousand miles removed from any others of their kind. They migrated up the mountain slopes to follow their favorite climate, while most of their kind migrated northward along the level into higher and higher latitudes.

How long ago this ice sheet melted away is known to a fair degree of approximation. The Great Lakes are a result of the glaciation and so is Niagara Falls in the river through which four of these lakes discharge. Niagara Falls exists because a hard rock layer overlies one of softer rock. Greater erosion of the softer rock beneath undermines the harder layer which breaks off in large fragments now and then. A particularly large fall of rock occurred a year ago. Thus the cataract is retreating upstream and thereby leaving a longer and longer gorge below the falls. According to this interpretation, the falls have retreated about seven and a half miles from the place where they took origin when the ice first cleared the region. The average rate of retreat per year, divided into the total length of the gorge, indicates that Niagara Falls has been in existence, though shifting its location upstream, for about 25,000 years.

How long the Ice Age endured is another question. Estimates run close to a million years. What caused this great climatic change is still another question. My time is up, but I'll take a split second more to say that I don't know. I find some comfort in my ignorance, however. No one else knows.

SCIENCE—THE GUARDIAN OF THE FAMILY HEALTH

By Dr. HUNTINGTON WILLIAMS

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I WONDER if you realize how much you owe to science, that ever-alert guardian of your health? Science means knowledge, or the knowing about all that goes to make up the world and the universe. For many centuries man has been trying to learn how to explain the mysteries that surround him, while the latest discoveries of science are constantly making possible new mysteries or miracles. This radio broadcasting is a good example of what we take for granted to-day, but would have considered a miracle fifty years ago. Some of the earliest scientific curiosity was concerned with the stars. This led to the science of astronomy. In those early days men were also curious about their bodies, and used to wonder and wonder about what it was that made them sick or kept them well. The best they could do was to guess, and they guessed that sickness was caused by evil demons or by their human enemies, who used magic or charms against them. Of course they guessed wrong, because they had no real science to tell them the truth.

It was not until about the time that Columbus was discovering America that modern science was having its beginning with the experiments of the great Italian, Leonardo da Vinci. Fifty years later Vesalius, the anatomy professor, laid further foundations in the structure of modern scientific medicine and from that time to this experimental scientific research has been constantly at work removing preventable disease and building up methods of health protection. Many branches of science have joined hands in this great task. Medical science has held a central position and has been assisted by chemistry, engineering and psychology, to mention but a few of the chief contributing sciences. What has been the manner in which these great forces have banded together to guard the health of the human family?

A hundred and fifty years ago smallpox was nearly as common a disease as measles is to-day. George Washington was pock-marked by it, and in Europe, kings and other royal and ordinary folk died because of it. There is no more brilliant page in the history of medical science than the one which bears the story of the young country doctor, Edward Jenner, whose great discovery resulted from the chance remark of a dairy maid. She said she could not take smallpox because she had had cow pox. This led Jenner to the most exact and careful scientific experimenting, and consequently we rarely see a case of smallpox any more. Vaccination is a word known to most school children because of personal experience.

Chemistry was the chosen field of service of France's greatest hero, Louis Pasteur. His features and not those of Napoleon adorn the postage stamps of the French nation to-day. Chemistry, so closely allied to modern medicine, led Pasteur to study fermentation and thence to the germ theory of disease. On he went to discover some of these tiny germ or microbe enemies of mankind and to make possible with the great German, Robert Koch, the discovery of many more. Every time we think of hydrophobia we should think of the Pasteur treatment for its prevention. Every time we drink a glass of pasteurized milk we should thank the science of chemistry for the man who has probably been responsible for the saving of more

human lives than any other single member of our race.

Let us think for a moment of the time when a drink of water anywhere might mean death from typhoid fever. Many of those who are listening know of this peril of the recent past. Which of the sciences guards the family health from the danger of that great killer? Engineering gives us the splendid filtration systems that guard the millions in our larger cities. Chemistry has added chlorination which is able to put the finishing touch on the very few and hardy germs that survive filtration or that are in our unfiltered rural water supplies.

Psychology, too, is one of the great sciences that is lending its aid in the protection of the family health. The modern mental hygiene movement which is based on psychology dates back only as far as 1908, when Clifford Beers wrote his marvelous autobiography, "The Mind that Found Itself." Ask your family doctor how many of his patients come to him because of some human problem that has distressed their minds or consciences. You will be surprised at the number. Such mental difficulties often develop and appear in the form of body symptoms. Mental tribulations are as old as mankind itself, and a striking illustration from Bible times is the story of the devils that went into the herd of swine which then ran violently down a steep place into the sea and perished. Nowadays science has shown that mental ailments may be treated just as effectively as physical ailments are treated and there is no sense of shame attached to them as formerly. This alone is a tremendous gain. Mental hygiene is also much concerned with happy family life and with the prevention of any possible modern "devils" caused by maladjustments or misfits within the family circle.

How can a person convince himself that the fruits of science are being thoroughly utilized in the protection of his own health and that of his relations? As in other fields, he must make a careful study and learn first what he may reasonably expect from his government, especially in cities. This will include among other services a pure drinking water supply, a safe milk supply, proper sewage disposal and a health education program. Then he should become aware of certain activities that he must do something about for himself. These have to do with personal hygiene, the development of health habits in childhood and the regulation of life in accordance with scientific discoveries that are fundamental in the modern art of "keeping well." To-day education in this worth-while art comes from a multitude of sources. The family physician has usually been the chief spreader of health information. The schools are now giving it more attention than formerly. Newspapers, magazines, the radio and modern advertising, some of which we can believe, are filled with the health message. The wise person is like the one who was always very cautious about the sausages he ate and insisted on knowing who had made them and from what material. So in matters of health education or advertising, it is important to know something about the sources and motives back of the health information before relying too much on it.

What the individual must do for himself is now the most vital problem in the modern public health or "keep well" movement. The periodic health examination, performed by the family physician or at a clinic, is a good foundation stone. Prenatal care for the expectant mother is another. Taking the babies to the child specialist and later to the dentist at regular intervals is a very valuable practice. Soon after the age of six months toxoid or toxin-antitoxin should be given to every child to prevent diphtheria, one of the most dreaded dis-

eases of childhood. Smallpox vaccine, too, is best given at about this same age. In these and many other ways the modern person is brought in contact with a point of view that health and disease are not mere accidents or chance happenings, but that positive health is something that can in many ways be planned for and to some degree ensured.

What of the future? There can be no doubt that our present health conditions will some day be looked back upon as quite barbaric. Much more scientific research is needed to give us a cause, a cure and a prevention for such death-dealing maladies as cancer, influenza and certain other fatal diseases. The unsanitary conditions now existing in the crowded and poorer sections of our cities, the present neglect of rural hygiene, the pressing need for an adequate attack on the venereal diseases through education, these and a host of other problems will long remain with us. For their solution we must look to our men of science. If we, every one of us, are on the alert to apply the scientific knowledge we now have in health matters, we can do much to prevent needless misery and suffering. Remember that health knowledge is not static, it is living and growing. It is up to us to make use of it. For example, we can now eradicate diphtheria if we desire sufficiently to do so. Are we doing anything about it? Let's get busy and join science as guardians of our families' health.

OUR PATENT SYSTEM

By Dr. EDWIN J. PRINDLE

PAST PRESIDENT, NEW YORK PATENT LAW ASSOCIATION

I VENTURE to say that to many readers our patent system is not much more than a name; that you scarcely know whether it is of any importance to our economic system. To learn what it has done for us, we need only to contrast the condition of our country before the establishment of our patent system with the condition after it had been finally perfected and really gotten to working. At the time when it was established, we were a group of purely agricultural and non-manufacturing colonies. Agriculture was conducted by the use of hand-tools, which the farmer not only guided and applied to his work, but which he had to drive by the power of his own muscles. Only the surface of the earth was tilled, and that was hardly more than scratched. The crops were light, and the labor so great that a man could cultivate but a few acres. There had been practically no improvement in agricultural implements for thousands of years. The American farmer was farming almost as the Egyptians did, when the Children of Israel were there.

Then came our patent system, saying, if any person would invent or discover any new and useful art, machine, article of manufacture or composition of matter, a patent would be granted, giving him the exclusive right, for seventeen years, to make, use and sell his invention; that is, the right to exclude every one else from any making, using or selling of it. As a result of this offer the farmer was gradually supplied with machinery which he had only to control and guide, and which often saved him even the trouble of walking. So great was the transformation effected that, with some crops, such as wheat, one man could do the work formerly requiring ten. Crops became more abundant and of better quality; the area which a man could cultivate was increased manyfold. On some of the larger up-to-date farms

to-day, where machinery is used to the fullest extent, only one man is required for every 250 acres.

If, during the Great War, the American farmer had not had this machinery to use, the shortage of labor caused by raising and equipping our army and navy would have made it almost impossible to feed our own people and would have left Europe to starve. The invention of farm machinery not only benefited the farmer; but the manufacture of that machinery became a great industry giving profitable employment to very large numbers of workers.

This effect on the American farmer and workers is only one example of many produced by our patent system. For instance, American-invented machinery makes shoes as good as any but the most expensive hand-made ones, and at prices with which foreign hand labor can not compete. This, too, created an enormous industry. By means of American-invented machinery, the American motor industry has been enabled to turn out high-grade automobiles by the thousands per day, and at prices impossible for foreign manufacturers to meet. This again afforded employment to an army of workers. The patent system has transformed and enlarged almost every branch of industry and, up to the time of the depression, made it possible for our workman to be so paid that he could live on a scale far above that of other countries, and still compete with cheap labor abroad.

Although most Americans are of European stock, and, therefore, are not naturally more inventive than Europeans, yet it is a fact that more than two thirds of all the inventions of primary importance, which have been made since the establishment of our patent system, were produced by American inventors. Only a small part of the wonderful development which I have sketched would have been attained, had it not been for the inducement of our patent system. Furthermore, this system is necessary to the bringing about of the perfection and commercial development of most inventions. For the making of an invention requires not only thought, but experiment and research. The devising and testing of possible solutions of the problem in hand, to ultimately find a way by which the desired result may be attained and that is sufficiently free from objections to make the invention practical and desirable; the building of a seemingly perfected device; and testing it under commercial conditions, often require costly facilities, endless patience and a large expenditure of time and money.

The result is that capital is almost always required to perfect an invention and to get it ready for marketing. The expense of developing a single invention not infrequently runs into thousands, and sometimes, as with the steam turbine, into millions. Without the possibility of recovering this expense, and making a profit on the invention, neither individuals nor companies could afford to make and perfect inventions. For, if there were no patent law, then when the invention had been perfected and put on the market, a competitor could copy it; and, not having had any expense of developing or perfecting the invention, he could sell it at a price far below that of those who, having perfected it, are burdened with the cost of doing so.

This is so true that if the immortal Edison could not have protected his inventions with patents, he never could have raised the capital which most of his inventions required for their development, and without which they could not have been produced. His expenditures in the development of inventions throughout his career amounted to many millions. In the latter part of the development of his incandescent electric light, Edison had as many as 100 men at work

in his laboratory. Not only this, but he sent expeditions all over the world before he found a vegetable fiber which could be made to serve as the filament of his lamp. When his electric light had been reasonably perfected, he still had to invent his clever electric distributing system, by which each lamp could adequately be supplied with current, independently of every other lamp throughout a large area. He then had to improve the dynamo, so that an enormous amount of current could be generated and maintained steadily at just the right voltage; and to invent the safety fuse to protect each lamp; the meter, the plugs, sockets, etc. Altogether, Edison took out 375 patents relating to electric lighting alone.

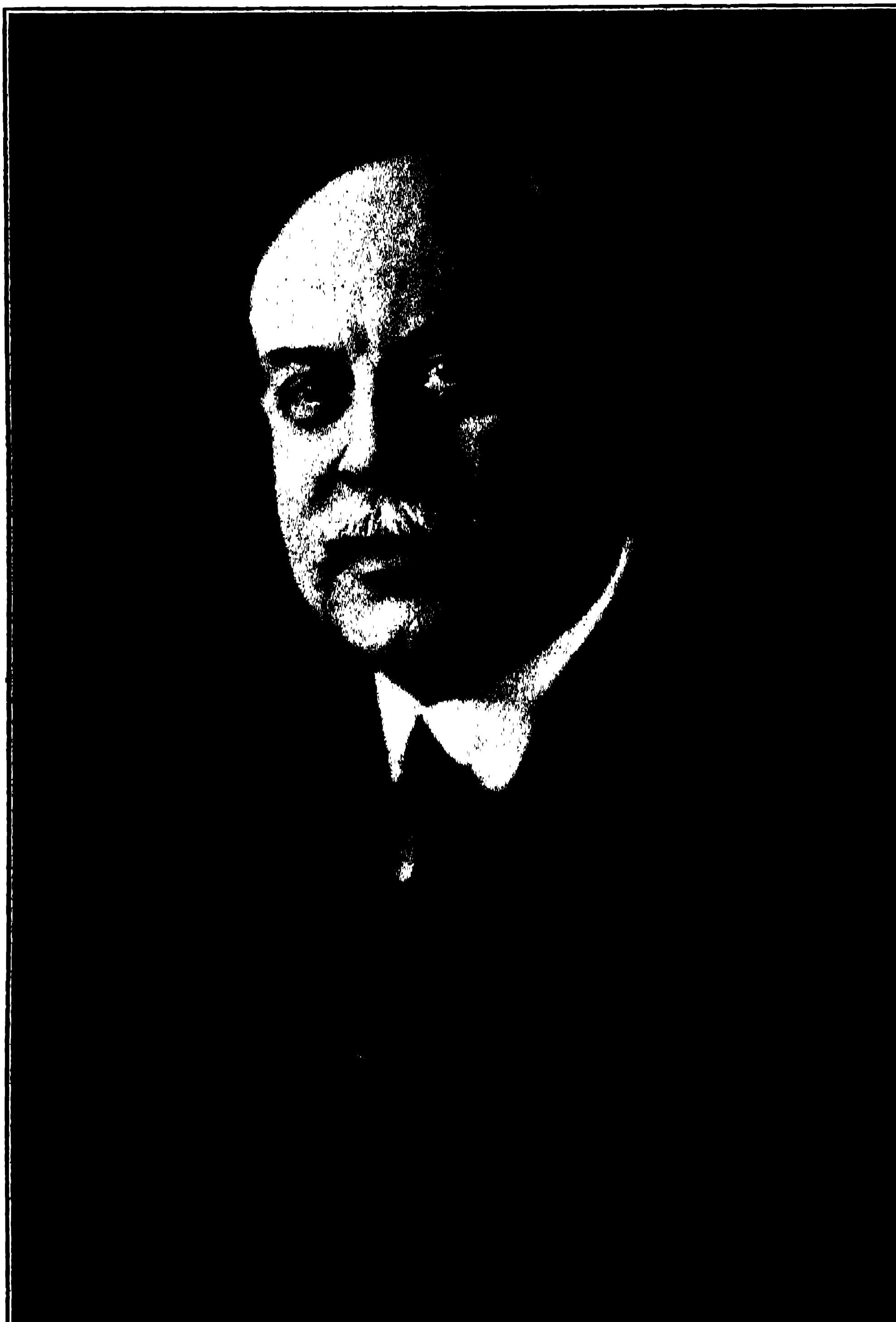
Among his multitude of other inventions are his carbon telephone transmitter—that transformed the Bell telephone from a mere laboratory curiosity into a commercially indispensable utility of the highest value; his phonograph—which is the foundation of the talking-machine and music reproducing art; and his motion picture projector—that for the first time gave the appearance of continuity and life to projected pictures, and which to-day is universally used; these inventions of great value to mankind required great sums for their development.

Without our patent system, the world would have been deprived of most of the inventions with which Mr. Edison blessed it, and which have added to the wealth, comfort, happiness, and employment of mankind beyond calculation. Mr. Edison's career also affords one of the most striking proofs that our patent system is an open door through which the man without capital, or college education, may possibly reach independence.

While labor-saving machinery may be responsible for some of the unemployment to-day, the same lure of the patent system that induced the inventing of the labor-saving machinery will surely cause the inventing of new products and the establishment of new industries that will afford employment to all our people. Who can say but even greater wonders than we have yet seen may be given to us in the future, if we keep the reward for their discovery sufficiently attractive to our inventive genius?

Because a patent for an invention is a monopoly, some think it is harmful, since most monopolies are so. But when the British Parliament, in 1623, prohibited the crown from granting monopolies of the sale of ordinary commodities, such as salt, it expressly excepted Letters Patent to the "first and true inventor" "of the sole working or making of any . . . new manufacture," because it recognized the great benefit these new inventions would bring to the realm. As a patent for an invention only gives the inventor a monopoly of that which he created, it takes nothing from the public; but at the end of seventeen years gives the invention to the public free.

Our patent system has been the primary factor in making America foremost among the nations, in agriculture, inventing and manufacturing. While there are other factors, the patent system is by far the most potent one. In its total effect it has greatly increased employment of labor and capital.



GEORGE KIMBALL BURGESS

THE PROGRESS OF SCIENCE

GEORGE KIMBALL BURGESS

SCIENCE has lost a capable executive—a devoted leader successful in both research and administration. On July 2, 1932, Dr. George Kimball Burgess was stricken with cerebral hemorrhage at his post as director of the National Bureau of Standards and died on his way to the hospital without regaining consciousness. Dr. Burgess was born on January 4, 1874, in Newton, Massachusetts, and died at the age of 58. In 1901, he married Suzanne Babut, of Paris, France, who survives him.

The extent of his responsibilities, all too many, perhaps, was a measure of his mental alertness and active interest. These continued to the end. The tact with which he dealt with situations was such as used a smile in place of an argument. He thought clearly and acted decisively in a manner to disarm criticism.

His practical turn was early reflected in his choice of a thesis subject, "The American Merchant Marine," on graduation from the Newton school system. In 1896, at the Massachusetts Institute of Technology, he conducted work on standards of pitch and collaborated in preparing Holman's "Precision of Measurement." He served successively in Harvard College Observatory, the University of Paris, the University of Michigan and the University of California.

His interest in pure science was shown by his choice of subject for his thesis—"Recherches sur la constante de gravitation," submitted to the University of Paris in 1900 for the degree of doctor of science. The University of Paris at the time awarded him the highest commendation, "Mention Très Honorable." His interest in this subject was renewed when, as director of the Bureau of Standards, he authorized a redetermination of this universal constant.

His book, "High Temperature Measurement," written jointly with Le-Chatelier in 1900, is, in revised form, still almost the only authoritative text on high temperature.

In 1903 Dr. Burgess was appointed assistant physicist in the Bureau of Standards. In 1905 he became associate physicist, and in 1913 he was appointed chief of the division of metallurgy. On April 21, 1923, the President of the United States appointed him director of the Bureau of Standards. His first annual report was a classic and has never been excelled as an administrative analysis of the work and achievements of a research organization.

As expert in metals, Dr. Burgess was deputed to go to the front to study the use of metals in warfare. He brought back a wealth of data as a foundation for research programs and the more efficient use of metals in war. As a member of the Aircraft Materials Specifications Board he rendered great service in the international standardization of materials used in aviation. His extended research program on railway materials was notably fruitful. To Dr. Burgess must be credited the introduction of pyrometry in the American steel industry.

He was perhaps the first to measure the temperatures of steel rails as they were formed in the rolls. He found finishing temperatures above certain critical points on the cooling curve of the steel, and recommended a reduction in the permissible temperature of finishing.

His ingenuity was illustrated by his micropyrometer, with which the melting points of microscopic particles of substances could be determined, thus opening up a new field in high temperature research. With this he was personally responsible for the determination of a vast quantity of valuable data widely used in the high temperature field.

His mastery of fundamental science was illustrated in his early proposal (1908) for a new type of standard of

light. This has recently (1929) been realized experimentally with great success in the laboratories of the Bureau of Standards. Radiation from a small aperture in a uniformly heated enclosure depends only on the temperature. Immersed in freezing platinum (the temperature of which is a constant of nature) a tube of thoria emits visible radiation of a quantity and quality which is invariable. Prospects are excellent that this reproducible source will be adopted as an international standard of candlepower.

Dr. Lyman J. Briggs, assistant director for research and testing (now acting director) of the Bureau of Standards, thus gives his impressions of Dr. Burgess:

"His office door was always open. Interruptions did not seem to worry him. His visitor found him dignified, but friendly, alert, attentive. He reached decisions promptly. His voice was low, his sentences crisp. His sense of humor was keen, and he responded to it with quiet body-shaking laughter. Sedentary in his habits, he had little interest in sports and games. Recreation to him meant a good book and a plentiful supply of tobacco, or a long drive in an open car with a friend. He loved the sea, and a long cruise was for him an ideal vacation.

"Dr. Burgess gave generously of his time and energy to further the interests of organizations engaged in the advancement of research and standardization.

"His memory will be cherished by the staff of the organization to which he gave the greater part of his life, and by his numerous friends in scientific and industrial circles, not alone in America but throughout the world."

THE FIRST SYRACUSE MEETING OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

THE ninetieth meeting of the association was held in the heart of a region famous for its universities and other scientific institutions. But Syracuse and the surrounding territory held many additional scientific interests for those who attended the meeting. Places of special interest in this connection included the Glacial Plunge Basin and Cross Channel in the vicinity of Green Lake, the Labrador Pond, the Moraine and Kettle Lakes at Tully, the Silurian and Devonian Exposures, extending from the Vernon Shale up to and including the Marcellus Shales, the Marl ponds, peat bogs, sandy fields and woodlands near Junius, the Thuja swamps around White Lake and the Salt Flats in the neighborhood of Onondaga Lake. So interesting were these places that several of the sections confined their programs to conducted field trips.

Those who had not visited Syracuse for several years were quite pleased to find that the host institution, Syracuse University, had grown from a small denominational school into a large thriving university of fourteen colleges, including Liberal Arts, Fine Arts, Law, Medicine, Engineering, Education, Forestry, Agriculture, Business Administration, Home Economics, Library Science, Speech and Dramatic Arts, Nursing, and Citizenship and Public Affairs.

The local committee, under the chairmanship of Dr. Hugh P. Baker, dean of the College of Forestry, gave much attention to the detailed work of preparing for this meeting and carrying it through to a successful conclusion. Much credit must be given to Dr. A. L. Elder, secretary of the committee, for his untiring efforts. A great deal of the program resulted from the activities of the local representatives, who, in many instances, acted for the section officials. Through the efforts of some members of the local committee excellent programs were presented by sections and societies which otherwise would not have had programs.

LYMAN HALL OF NATURAL HISTORY

The weather was ideal, except for one day which was a little too warm for some members. The delightfully cool weather both before and after this one day indicated, however, that it was really an exception.

Although only 504 registered, there were at least three or four times that many in attendance. Many who attended sessions drove their cars to the meeting, hence had no tickets to validate. A large number of these were provided with society programs and, therefore, felt no need to register with the association. Many others attended their first meeting of the association and failed to understand the desirability of registering. This was especially true in the sections devoted to chemistry, medical sciences, engineering and agriculture. For example, over 150 attended the "Land Use" symposium, but not over 10 per cent. of these registered. One hundred and seventy-five attended the sessions of the medical section on Friday, and yet only about a dozen registered. The registration, therefore, gives no good approximation to the number who attended scientific sessions.

The general programs of the association turned out to be quite interesting. All seven general addresses given in the late afternoon proved to be quite popular. Audiences at these sessions ranged from about one hundred to three hundred. As usual, the general sessions in the evening were well attended.

Dean Hugh P. Baker, chairman of

the Syracuse local committee, officially opened the meeting with a welcome from the local committee. Chancellor Charles Flint, of Syracuse University, followed with a hearty welcome on behalf of Syracuse University. Dr. John J. Abel, president of the association, responded to these words of welcome and introduced Dr. J. McKeen Cattell, who in turn introduced Dr. E. L. Thorndike, the speaker of the evening.

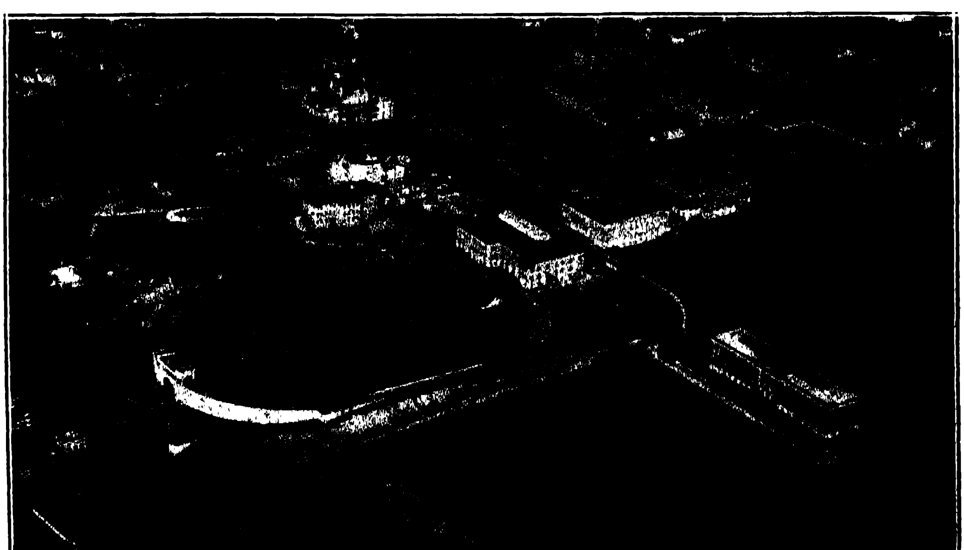
In delivering his address on the "Psychology of Capital," Dr. Thorndike said, "If science is allowed to do what it can do, enough material capital can probably be created from nature within a single life-time to give each of the 50 per cent., who now have least, much more than he would at the end of his life transmit to his children if he now received an equal share of all the capital owned by men." He branded as a dangerous myth the notion that manual labor is the creator of all capital and that capital as such is the oppressor of labor. Following Dr. Thorndike's address there was a general reception in the ballroom of the Hotel Syracuse.

On Tuesday evening Dr. J. O. Perrine gave a popular demonstration of the physical principles which have been used to make television possible.

On Wednesday evening Professor W. F. G. Swann gave a popular demonstration of short wave-length radiation discoveries which have led up to the discovery of cosmic rays. He showed how radium emanations from the earth ionized 1,000 molecules in each cubic centimeter of air. He demonstrated that when the radium emanations are filtered out, powerful rays called cosmic rays pass through the filters to produce a residual ionization. He proved further that these rays come vertically from above the earth.

On Thursday evening Dr. Graham Lusk gave an historical address in which he reviewed the contributions of the German scientist, Max Rubner, to the science of nutrition. On Friday evening Dr. Henry Crew outlined the advantages of making science known generally. He pointed out that many of those scientific principles exhibited as scientific curiosities at early World Fairs have contributed most to human progress.

Noteworthy general addresses were given at other sessions by Dr. Richard



SYRACUSE UNIVERSITY FROM THE AIR

THE UNIVERSITY FROM THE ROOF OF THE HOTEL SYRACUSE

Thurnwald, of the University of Berlin, Dr. Rodney H. True, of the University of Pennsylvania, Dr. W. G. Smillie, of Harvard University, Dr. Thomas Parran, Jr., health commissioner of New York State, Dr. Dixon R. Fox, of Columbia University, Dr. Frederick Slocum, Dr. E. R. Hedrick, of the University of California at Los Angeles, and Dr. W. B. Carver, of Cornell University.

Technical sessions, which were especially noteworthy for the program material presented and for bringing together important leaders in research, included those devoted to symposia on "The Biological Action of X-rays," "Land Use," "Demand and Supply," "Aerial Photographic Surveying and Mapping" and "Mental Hygiene."

Although the association held no official science exhibition, a number of very good exhibits were secured by the local committee. Especially noteworthy were the medical exhibits, the chemical ones and those of the College of Forestry.

CHARLES F. ROOS

MEDAL DAY MEETING OF THE FRANKLIN INSTITUTE

IN accordance with its long-standing custom of presenting its medals and other awards on the third Wednesday in May, the Medal Day exercises of The Franklin Institute were held this year in the hall of the institute on May 18. At this time fifteen honors were bestowed, and two papers by the recipients of its highest award—the Franklin Medal—were read. The medalists represented the United States, Great Britain, Germany and Sweden.

The Franklin Medal was founded in 1914 by Samuel Insull, of Chicago, Illinois, a long-time member and friend of The Franklin Institute. This medal is to be awarded to "those workers in physical science or technology, without regard to country, whose efforts, in the opinion of the institute, have done most to advance a knowledge of physical science or its application."

Two Franklin Medals are awarded each year, usually to an outstanding scientist of the United States and to some scientist from some other country. This year the first Franklin Medal was given to Dr. Ambrose Swasey, of Cleveland, Ohio, "in recognition of his development of methods and his invention of appliances for making machines, tools and instruments of the highest precision, of the design and construction of the mountings of many of the world's largest telescopes, and of his scientific vision in the establishment of the Engineering Foundation for the promotion of research and its application in the various fields of engineering."

The second Franklin Medal was

DR. PHILIPP LENARD

awarded to Dr. Philipp Lenard, of the University of Heidelberg, Germany, "in recognition of a life work devoted to fruitful research in physics, in the course of which he added greatly to scientific knowledge and especially showed that it was possible for cathode rays to exist outside the generating tube and determined the effects produced by such rays; he also discovered the electronic nature of the emission from surfaces upon which ultra-violet light falls, as well as the basic laws of photo-electricity."

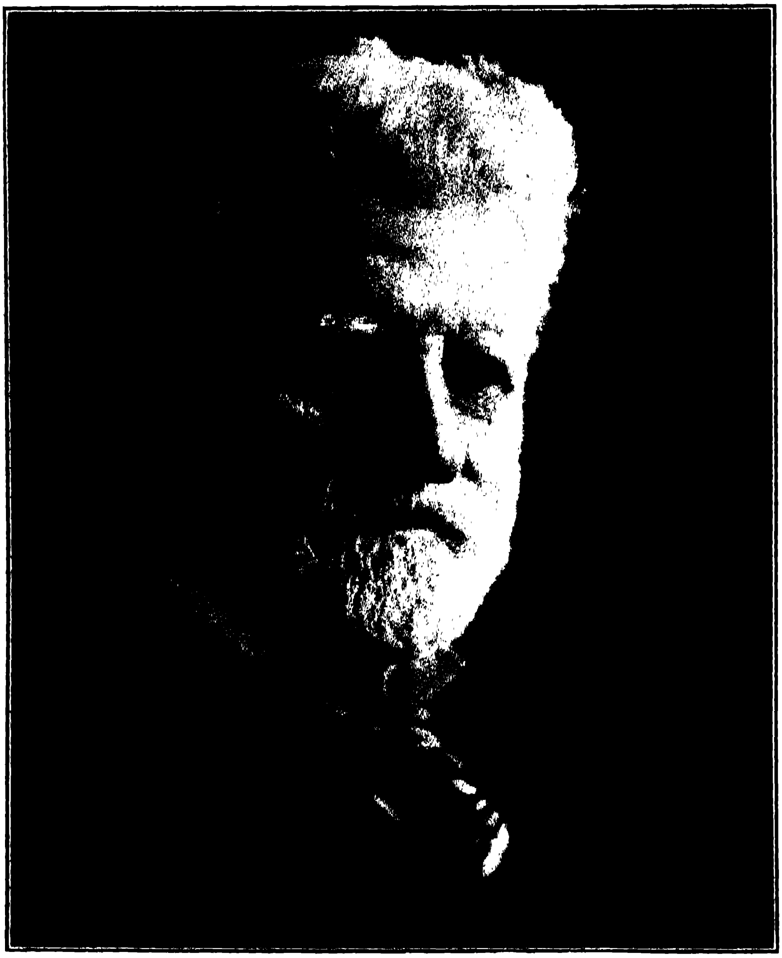
Dr. Lenard was unable to come to America to receive his medal in person because of his age. He was represented by Dr. O. C. Kiep, the German consul general in New York City.

The two addresses of the Franklin

Medalists were then read. First was one prepared by Dr. Lenard, and delivered by his friend and former associate, Dr. Charles B. Thwing. The title was "Some Scientific Views." Dr. Lenard told how, after several years of fruitless research, he had finally, forty years ago, succeeded in obtaining cathode rays in the open air, through the aluminum window of his tube. "First and foremost," he said, "I succeeded in showing that the rays are not projected atoms or molecules, for they entered into perfectly evacuated spaces in which one had not been able to produce them and took with them nothing of the nature of the matter. No trace of gas appeared in these spaces; they remained as empty as originally. Evidently the 'cathode rays' were therefore no 'radiant matter'; they must be something still more remarkable. It was then shown that they were projected negative electricity; one had here for the time obtained electricity as such, previously one knew it only when on electrified bodies or flowing in wires, but without knowing whether it was separable from these material carriers generally and was of itself a particular substance capable of being investigated. It was the negative electricity of these rays become visible. It is to-day indeed common knowledge that it consists of the small particles, the electrons, like the material of the atoms. It is these electrons, therefore, which go out from the window of the discharge tube in the form of rays, with very high velocity."

After summarizing the steps leading to the modern conception of the identity of matter and energy, Professor Lenard then presented his view of the ether. "The velocity of light is not an accidental thing and indeterminate; therefore, there must be in space something determinable relative to which it is to be considered, this something is the ether. . . . Going even further, according to the view obtained concerning matter as a special case of energy, it is to be accepted that in general every amount of energy of whatever sort has its own associated ether which always accompanies it and surrounds it as an envelope, with an attenuation extending to great, even infinite distance. This new conception appears to ascribe to the ether an especial rôle; it lets it, the ether, appear as the active agent of gravitation. In fact, it is true that, as we saw, weight, gravitation is an attribute not only of matter, but of every amount of energy, and gravitation extends, according to Newton's law, out to infinity. In fact, by means of gravitation every amount of energy is everywhere like every atom; gravitation fails at no distance; and this objective presence of all the energy of the world may lie in the presence of their ether envelopes. Ether and matter do not therefore make up the universe, but ether and energy, and these two do not stand in opposition to each other, but belong always and inseparably together; to every quantity of energy belongs its ether."

Dr. Swasey personally delivered his paper, on "Astronomers and Their Telescopes." In it he gave some reminiscences of his experiences with many great astronomers and paid particular tribute to his friend and partner, the late Mr. Worcester Reed Warner, cofounder with him of the Warner and Swasey Company, famous builders of fine machine tools. "Throughout a half century," said Dr. Swasey, "notwithstanding the fact that our work in building engines of industry was of much more importance from a financial standpoint than building engines of science, I am pleased to say that the opportunity of cooperating with the men interested in astronomical work was a rich experience which we greatly prized." Outstanding among observatories he cited the Mount Wilson Observatory of the Carnegie Institution of Washington. "Among our great men," he stated, "we have some great dream-



DR. AMBROSE SWASEY

ers and some great builders, but in Dr. George Hale we have a great dreamer and a great builder. He dreamed of an observatory on top of Mount Wilson and he built the most magnificent institution of its kind in the world. To tell you of the work of the 100-inch and of the 60-inch and the many other unique telescopes there is a story which includes all branches of astronomy. He and his distinguished staff, which includes Adams, St. John, Hubble and many others, began with the studies of our sun and now are able to tell us not only many new things about the sun and the stars, but are giving us a much clearer conception of the structure and extent of the universe. It is interesting to note that on the other side of the continent the young, enthusiastic Dr. Shapley at Harvard College Observatory has verified and extended this work of the Mount Wilson astronomers."

Both the papers of Dr. Lenard and of Dr. Swasey will be published shortly in full in the *Journal of The Franklin Institute.*

The Medal Day exercises concluded in the evening with a dinner at the Bellevue-Stratford Hotel, in honor of the medalists. Several of the honored guests, Mr. Nathan Hayward and Dr. Howard McClenahan, delivered brief addresses. About 250 visitors attended.

FOREST FIRE AS A ROCK DISINTEGRATING AGENT

THE conventional list of the forces which result in the breaking and pulverization of rocks usually includes the following (from Hilgard): Effects of heat and cold on rocks, effects of freezing water, glaciers, flowing water, wave action, winds and sand storms. Usually the effects of heat are attributed solely to solar radiation and insolation. The great heat of forest fires does not seem to have been considered as of sufficient importance to warrant inclusion in such lists.

The four photographs accompanying this note illustrate, however, the very appreciable scaling and fracturing of granitic rocks in northern Idaho as a result of the burning of dead trees which had fallen years ago. Fig. 1 shows the marked scaling where a section of a large tree had almost completely burned before it rolled down to a new position. Fig. 2 shows the remains of another burned stub that by its heat of combustion fractured the fresh rock chips nearby. Fig. 3 shows a rather large rock segment broken off by the burning of another windfallen tree. In Fig. 4

FIG. 1

FIG. 2

FIG. 3

FIG. 4

the original dead tree top lay in the crotch of the broken boulder before the fire and only the top segment of this rock showed that it was the result of a fresh fracture undoubtedly caused by the heat of the burning wood.

As the materials *in situ* prove that fire has been of universal occurrence in the past throughout all present forest types of the United States, and as the fire records of the last half century prove that forest fires are still altogether too frequent and wide-spread, it may be that the resultant rock fracturing is equally as important as that resulting from some of the other causes conventionally listed in the texts on soil formation.

H. T. GISBORNE

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SEPTEMBER, 1932

THE EXTREMES OF NATURE

By Dr. B. S. HOPKINS

PROFESSOR OF INORGANIC CHEMISTRY, UNIVERSITY OF ILLINOIS

THE human mind is naturally interested in those affairs which may be described by the use of the superlative degree. Long journeys are undertaken to see the highest mountain, to visit the largest building, to view the most beautiful sunsets and to meet the most outstanding individuals of our generation. Keen curiosity is aroused by the largest elephant in captivity or the smallest dwarf of the human race; or by the strongest man, and the tiniest living creature which may be seen under a microscope. We wonder at the most powerful beacon light for the guidance of our night-flying airplanes and the smallest electric lamp that has ever been made. We listen with awe to the tolling of the world's largest bell and look with a feeling almost akin to reverence upon the smallest watch that keeps accurate time. Things of ordinary dimensions are commonplace, but any item whose description requires the use of the superlative challenges our attention and arouses our curiosity.

Nature has given us materials with a wide range of properties and of usefulness. These natural substances are capable of modification by various methods with the development of new properties or the strengthening of those properties which are to be regarded as characteristic. If the watchmaker desires a spring with the greatest possible elasticity and permanence he is interested in knowing what metals may be used and what treatments of these metals are necessary in developing to the highest degree the desired properties. If a machinist requires a hard and tough metal for a bearing he is likewise interested in finding these qualities among the metals and intensifying them until he is satisfied that he is using the best material which is available. The physician who is called upon to fight a disease finds that a number of remedies may be used, but he is anxious to employ the best one for his patient. So our natural curiosity which is stimulated by the use of the superlative degree is reinforced by the needs of our modern civilization. A study of the extremes of nature soon passes far beyond the realm of mere curiosity and establishes itself as a means by which we can measure our progress in solving the problem of selecting the best material to serve our purpose in a certain specific application.

Let us begin our detailed study by attempting to answer the question: What is the heaviest substance known? An answer to this question must be prepared with some care because there are many substances which are extremely heavy, and differences are generally small. Obviously the heaviest substance known to man must be a solid, because solids in general contain matter in the most condensed form. There are many

rocks and minerals which are characterized by their unusual weight and many devices are used to concentrate valuable ores by taking advantage of their great weight. But there are few natural mineral substances which are more than 7 times as heavy as an equal volume of water and there is not one listed that is 10 times as heavy as water. On the other hand, at least 17 of the metals which we use are more than 10 times as heavy as water. The familiar phrase "as heavy as lead" is used to convey the impression of great weight, because every one is familiar with the excessive weight of this common metal. Yet lead is far from being the heaviest of the metals, since gold, mercury, platinum, tantalum, thallium, thorium, tungsten and uranium are all metals which are heavier than an equal volume of lead. In selecting the heaviest metal known, care must be exercised in preparing the sample for examination, because the weight of each metal varies somewhat with its method of preparation. Thus when gold is distilled in a vacuum it has a density of 18.88; when it is drawn annealed its density is 19.26; cast gold has a density 19.3 and when the gold is wrought it has a density of 19.33. So comparisons should be made between metals which have been prepared in a similar manner. The heaviest metal in general use is platinum, whose density varies from 20.9 to 21.7. Closely related to this costly metal are two others, osmium and iridium, which are less familiar than platinum. Both are slightly heavier than platinum. Osmium has a density which varies from 21.3 to 24 and in its most compact form osmium must be given credit for being the heaviest substance known upon our earth.

What is the lightest substance known?

As we looked among solids for the heaviest material, so our search for the lightest substance will be among gases, since in these we have matter in its most dilute form. Our familiar comment "as light as a feather" is not very expressive when we are speaking of gases, because a feather is heavier than air, while many of our gases are lighter than air. In speaking of the densities of various gases it is customary to compare their weight with that of an equal volume of air. All gases which are lighter than air are said to have densities which are less than 1. Acetylene, ammonia, carbon monoxide, ethylene, methane, neon and nitrogen are all lighter than air; of this list the lightest gas is methane, and it is about half as heavy as air. The inert gas helium has a density of 0.138, so its weight is about one fourth that of an equal volume of methane and less than one seventh that of air. Although helium is exceedingly light, it is not the lightest gas known, since a liter of hydrogen weighs about half as much as a liter of helium. The lightest gas that we know is hydrogen, whose weight is less than one fourteenth that of air. At the present time hydrogen gas must be considered the lightest substance which is available for general purposes. There is a question however as to whether or not it can fairly be described as the lightest substance known. The worker in high vacua and x-ray tubes deals with streams of electrons and these must certainly be lighter than hydrogen since they may be thought of as being the lightest fragments of disrupted hydrogen atoms.

The most interesting application which depends upon the lightness of hydrogen is in the filling of balloons. Its ability to lift objects from the surface of the earth is truly remarkable, since it can support an object more than 14 times its own weight. When we remember that a man finds difficulty in lifting more than his own weight, we see how great the lifting power of hydrogen is. As a gas for filling balloons it

would be almost ideal except for two facts: it burns very readily and diffuses rapidly through the fabric of the gas bag. The ease and rapidity with which hydrogen burns makes its use in dirigibles extremely dangerous. As a consequence there is a distinct advantage in the use of helium, in spite of its scarcity, its greater initial cost and its lower lifting power.

What substance can be considered the hardest material known?

In order to compare the hardness of various substances it is necessary to agree upon what we mean by the term "hardness" and then to find some method of measuring this characteristic. When an engineer says that a certain metal is hard he may have in mind a variety of things. When the term is applied to the bearings of machinery, it means the ability to resist wear between moving surfaces in the presence of a lubricant; when referred to steel rails and car wheels, it implies resistance to friction without lubrication; in machinery for crushing rocks it refers to the ability to resist both abrasion and shock; in metal which is to be machined, it applies to the difficulty in cutting or working; and in cutting tools it frequently indicates the ability to hold a cutting edge. It is obvious that resistance to wear is quite a different thing from the resistance to cutting. Consequently, a measure of hardness which will permit the comparison of one metal with another is difficult or impossible. The most common means of measuring hardness from the engineering point of view is by determining the resistance to indentation by some especially hardened implement. The Brinell method uses a steel ball 10 mm in diameter which is applied under pressure, the amount of indentation giving an index to the hardness of the metal under examination. Sometimes a cone of hardened steel replaces the ball; sometimes the hardness is estimated by allowing a pointed hammer to fall from a definite height and measuring the height of the rebound; sometimes hardness is determined by the depth of hole cut by a given number of revolutions of a standard drill applied at definite speed and pressure. These various methods of measuring hardness do not give concordant results when they are applied to the same piece of metal. As a consequence we must conclude that our methods of making these measurements are at fault because they do not all depend on the same property of the material being tested. If some one test is selected and this is applied to a number of metals, comparative results are obtained. It is evident, however, that these methods are difficult to apply to the problem of selecting the hardest substance known, because they nearly all contemplate the use of some tool which is harder than the material being tested. It must also be recognized that extreme hardness is frequently accompanied by brittleness. As a result these engineering tests for hardness when applied to all substances might easily result in breaking the object which is under examination.

The mineralogist is intensively interested in the relative hardness of the rocks and minerals which he examines because such a study gives one of the most useful methods for the identification of various native materials. In such a study precise measurement of hardness is not necessary, so there has been devised Mohs' "harness scale," which is based upon the ease with which the smooth surface of a mineral is scratched by another mineral or by a file or knife. Ten well-known minerals are selected and numbered in the order of increasing hardness. These typical minerals composing the scale of hardness are as follows:

1. Talc, including minerals which feel greasy to the hand.

2. Gypsum; those minerals which are easily scratched by the finger-nail.
3. Calcite; difficultly marked by the finger nail, but readily cut by a knife.
4. Fluorite; easily scratched by a knife.
5. Apatite; difficultly scratched by a knife.
6. Orthoclase; scratched by a file; hard enough to scratch glass.
7. Quartz; little touched by a file; scratches glass readily.
8. Topaz
9. Sapphire
10. Diamond.

The intervals between the various members of this hardness scale are not uniform. For example, there is not much difference between the hardness of gypsum, which is No. 2, and that of calcite, which is No. 3, while there is a large difference between the hardness of sapphire, No. 9, and the diamond, No. 10. This last interval is so great that an expert in the study of hard materials assures us that there is greater difference between the hardness of No. 9 and No. 10 than there is between No. 1 and No. 8. Such statements as these justify the opinion that the diamond is the hardest native substance that we know.

There still remains the possibility that some substances which are artificially prepared are harder than the diamond. The high temperatures which have been reached in the electric furnace have made possible the production of many extremely hard products. These are mainly centered around the elements carbon, boron and silicon and the compounds of these elements with certain of the metals. The most important commercial product of this sort is the familiar substance known as carborundum. It is silicon carbide (SiC), which is made by heating a mixture of silica and carbon to a high temperature in an electric furnace. Carborundum has a hardness nearly equal to that of the diamond, and the obvious advantages which it possesses as an abrasive have led to its extensive use in the manufacture of various kinds of grinding tools. Many extremely hard substances have been formed by making the carbides, borides or silicides of such metals as aluminum, calcium, vanadium, titanium, zirconium, molybdenum, tungsten, tantalum and chromium. Silicon boride and aluminum borocarbide are among the hardest artificial products, and a carbide of boron is so hard that it is recommended for use in polishing diamonds. Occasionally the claim is made that one of these products of the laboratory is actually harder than the diamond, but it is unlikely that such a goal has yet been reached. The best conclusion that we can reach is, therefore, that it is undoubtedly still true that the diamond is the hardest substance known.

The most familiar use of the diamond is as our most highly prized gem. The United States buys and wears more diamonds than any other nation. It has been estimated that the diamonds owned in this country exceed 4 billion dollars in value, an average of between \$150 and \$200 for each family. In spite of these enormous values, it is true that more than half of the world's diamond production is consumed for industrial uses and not as ornaments. For industrial purposes low-grade crystals are used, in such instruments as glass cutters, engravers' tools and lathe tools. A form of diamond known as carbonado or carbon, which does not show a marked crystalline structure, is very tough and durable and may be slightly harder than the gem stones. It is used extensively in making bearings for accurate chronometers, meters and various other laboratory instruments, for making dies for drawing metals out into fine wire; for core drills which are so useful in mining operations; and for saws for cutting stones. Diamond dust finds important use in cutting and polishing gems and other hard materials. South Africa is by far the most important diamond-producing area, nearly 95 per cent. of the world's diamonds being mined there. The United States produces very few

diamonds, Arkansas being the only locality in which diamonds are actually mined. The largest diamond found in this country was located in 1924 and weighed a little over 40 carats. This is quite small when compared with the world's largest, the Cullinan, originally weighing 3,106 carats, which is owned by the King of England; or the Kohinoor, perhaps the most famous of all diamonds, which now weighs a little over 100 carats, although its original weight was about twice as much.

Let us now consider the question: What is the most ductile substance known?

The property of ductility is generally understood to refer to the capacity for being drawn into a wire. A little broader understanding of this term would include also pliability or malleability. So the most ductile substance would be that substance which can be drawn out into the finest wire or hammered out into the thinnest sheet.

These are properties which belong almost exclusively to the metals. In studying the metals with respect to ductility and malleability we must remember that both the purity of the metal and the method of preparation have a profound influence upon ductility and malleability. In general, the presence of impurities tends to make a metal brittle, thereby decreasing the ductility and malleability. A good example of this effect is found in the history of the tungsten filaments now used so universally in our electric light lamps. When attempts were first made to produce a drawn tungsten wire the metal was found to be much too brittle. But when the metal was prepared in a high state of purity and given a skilful heat treatment it was found to be readily ductile. We have reason for believing that many of the less common metals which are now thought to be hard and brittle may prove to be pliable and capable of being worked successfully when we get them sufficiently pure and learn what conditions of temperature are best suited for working them. Sometimes it happens certain impurities present in a metal in definite proportions have the effect of increasing the pliability of a metal. Thus wrought iron, a product which is outstanding for its softness, toughness, malleability and ductility, contains a certain per cent. of carbon, phosphorus and slag, although these impurities in iron ordinarily produce hardness and brittleness. As a result of the varied influences of impurities, we shall do well to pursue our study of ductility without respect to the purity of the metals under consideration.

Gold, silver and copper have long been regarded as the most ductile and most malleable of the metals, although tin, platinum, lead and hot zinc, as well as many of the less common metals, possess these properties in decreasing degree. Gold occupies a position at the head of this list because it has been drawn into wire so fine that it can not be seen without the aid of a microscope. It is reported that gold wire has been made so fine that over 3,000 meters of it are required to give a weight of 1 gram. The significance of these figures is perhaps better understood if we say that an ounce of such a wire would be over 50 miles long. Gold leaf has been made so thin that 1,500 sheets must be stacked together to equal the thickness of an ordinary sheet of printing paper, and a pile one inch high would contain over 300,000 sheets of gold. An ounce of gold beaten out to such extremely thin sheets would cover 189 square feet of surface, while an entire tennis court would be covered by less than one pound of this precious metal. Commercial gold leaf contains a little over 2 per cent. of copper and 2 per cent. of silver, these metals being added for the combined purpose of improving the color and making the thin sheets more rugged in handling. A

thickness of 1/200,000 of an inch is usual in the gold leaf which finds actual use for such purposes as making window signs, artistic designs in glass and monograms on hat bands. Great skill is required for the preparation and handling of such thin sheets of metal. The gold-beaters' art, as carried out today, is essentially the same as that employed by the Egyptians at least 3,000 years ago. This is probably the oldest skilled trade which has successfully resisted the encroachments of the machine age. As carried out in a modern plant, the first step consists in passing an ingot of metal through rollers until it has approximately the thickness of heavy writing paper. This sheet is then cut into one inch squares and 200 of these are placed between the leaves of heavy rice paper about 4 inches square. This book is then slipped into a heavy parchment cover, placed upon a firm pillar and beaten with an 18-pound hammer for 20 minutes. At the end of this process each sheet of gold is nearly 4 inches square, and thinner in proportion than the starting sheet. Each of these is then cut into 4 parts, making 800 sheets in all, which are placed between leaves of gold-beaters' skin, a material prepared from ox gut. Once more the book of leaves is beaten, this time for about an hour and a half. The 800 gold leaves are each cut into quarters and each piece is again placed between sheets of gold-beaters' skin. The final stage in the preparation consists of beating for 4 hours with a hammer weighing about 8 pounds. This produces 3,200 sheets of gold ready to be trimmed and packed between the pages of a paper book. While this description sounds simple the process requires a high degree of intelligence and a skill which is only acquired by long years of apprenticeship.

For many centuries gold has been considered the most ductile and the most malleable substance known. It is still to be considered as occupying a supreme position in these respects. But modern scientific endeavor has produced a rival at least as far as ductility is concerned. This is a special form of tungsten which is known as ductile tungsten. It is prepared from very pure metal by electrical heating and mechanical hammering in an atmosphere of hydrogen. When this progess has produced a relatively small wire, then the tungsten may be drawn through a diamond die in the open air and in this way its size may be reduced until a diameter of 0.005 mm is obtained. Such a wire is about 1/15 the average size of a human hair and it is only slightly larger than the finest gold wire ever produced. It is quite possible that further work with tungsten may produce a wire smaller than any which can be made of gold, but, at the present time, gold is still to be considered the most ductile as well as the most malleable of our metals.

What is the highest temperature that has ever been reached?

The most general method of producing moderately elevated temperatures is by burning some form of solid fuel like coal or coke in the air. Such a plan can be used to obtain a bright red temperature which will be in the vicinity of 700° C., sufficient to melt tin, lead or zinc. If a forced draft is used the temperature may be raised considerably above white heat (1200° C.), and by this means copper, nickel and iron may be melted. For higher temperatures the fuel is sometimes powdered and blown into the furnace by an air blast, thereby producing a mixture which burns rapidly, producing a temperature of about 1600° C. Such a furnace is used in the manufacture of Portland cement. If a still higher temperature is desired it may be obtained by replacing ordinary air in the blast with oxygen, thereby avoiding the cooling effect of the large proportion of nitrogen which the air contains. If a combustible gas is used with oxygen,

the highest temperatures available from a burning fuel are obtained. Thus a blast lamp burning coal gas with oxygen yields a temperature of about 2000° C., while an oxy-hydrogen flame is said to reach a temperature of 2800° C., and an oxy-acetylene flame to give temperatures up to 3500° C. The newly devised apparatus for utilizing the atomic hydrogen flame gives an intensely hot flame which can be applied to small volumes. In this way a temperature of 3800° C. can be obtained. This temperature is sufficient to melt or vaporize every known substance, with the possible exception of carbon and the new grinding material tantalum carbide.

Electric furnaces have recently come into general use for a wide variety of applications. In general these depend on the transformation of electrical energy into heat through the medium of some resistor. A wire wrapped around a core forms a furnace which may be used up to the temperature at which the metal begins to soften or react with the air or other material with which it comes in contact. Alloys of nickel and chromium are widely used for the windings, and with these temperatures in the vicinity of 1000° C. may be obtained. If molybdenum or tungsten wire is used and the hot metal is protected from air, temperatures up to 1600° C. are obtainable. If the furnace is constructed of concentric cylinders of sheet metal such as molybdenum, the inner sheet being the heat unit and the air being pumped out, a temperature of 2000° may be reached. Still higher temperatures may be obtained in an arc type of furnace in which a powerful electric current is passed through a lead of carbon granules which serve as the resistor. The furnaces in which carborundum and artificial graphite are made are of this type, and with these, temperatures of 3500° or 3600° C. are reported. This method of producing heat is very effective for certain purposes, but it is very difficult to control and is quite lacking in uniformity, a quality which is generally much desired. If the object which is to be heated is an electrical conductor it may be heated effectively in a type of furnace which is known as the induction furnace. If a high frequency current is passed around a coil which surrounds the material to be heated, eddy currents are induced which produce a rapid rise of temperature. In this manner a piece of metal may be melted quickly in an evacuated tube. The limit to the temperatures which may be produced by these devices is the temperature at which the material under treatment is vaporized. It is claimed that a temperature of about 3600° C. has been obtained in this way, but it is difficult to maintain it for any considerable time.

Recent efforts have been made to obtain much higher temperatures than can be obtained by the use of fuel or the present types of electric furnace. The principle involved in this plan consists in concentrating into one spot the sun's heat from a considerable area by means of a series of mirrors and lenses. This method has already produced a temperature of 3000°, and it seems likely that the next few years will witness the recording of temperatures which are vastly greater than any which can be produced in to-day's laboratories. This method of heating has distinct advantages in that it possesses considerable uniformity and can be transmitted through the walls of an evacuated vessel without heating the walls themselves.

The measurement of high temperatures presents an interesting study. The simplicity and general dependability of the mercury thermometer makes its use almost universal within the ordinary range. Above 500° C. some other method of measuring temperatures must be used. Advantage is taken of the fact that gases expand fairly uniformly as the temperature increases, and various gas thermometers are supplied for

use at moderately elevated temperatures. These may be filled with hydrogen, helium, nitrogen or argon, and temperatures are estimated by change in volume or pressure. Gas thermometers are both accurate and simple to operate. Electrical devices for measuring high temperatures are usually called pyrometers. They have the advantage of delicacy, adaptability and wide range, but they are usually complicated and require considerable skill in their use. There are two general types of pyrometers of this sort. Thermocouples depend upon the production of a thermoelectric force when the junction of two different metals is heated. The E.M.F. is small and so the instruments are not very sensitive. Base metals are useful for certain purposes up to about 1100° C., but generally for greater dependability and high temperatures the metals of the platinum group are selected. The second type of pyrometer depends on the increase in the electrical resistance of a wire when the temperature is raised. Platinum wire is generally used in such instruments. Skilful use of such devices gives accurate readings up to 1000° C. but temperatures as high as 1400° may be measured by these devices.

It is obvious that none of these methods of reading temperatures are usable at the extremes of the scale. For practically all readings above the melting point of platinum (1774° C.) some form of optical pyrometer is used. These are of many forms, but they all depend upon the fact that as the temperature rises the color of the emitted light changes. One successful type of optical pyrometer is so constructed that the observer sees the field divided into two parts. One part is illuminated by a standard lamp and the other by the surface whose temperature is to be measured. The instrument is so constructed that by adjusting it until the two halves are equally illuminated the temperature may be read from a scale. In another type the filament of an electric lamp is compared with the color of the surface whose temperature is to be measured. The lamp filament is heated until it disappears when viewed against the hot body; from the current required to make the filament disappear the temperature may be calculated. Such instruments may be used to excessively high temperatures, but it is difficult to obtain accurate results at such extremes of temperature.

The highest temperatures which have been sustained for a considerable time and measured with reasonable accuracy are in the neighborhood of 3500 or 3800° C. Some claims are made that still higher temperatures have been produced, but it is impossible to maintain them for any length of time or to apply them to more than a very limited area. Such temperatures seem to be very high since all known substances are either melted or vaporized by such extreme heat. However satisfied we may be in contemplating the results of scientific endeavor in this direction, these temperatures sink into insignificance when they are compared with those which we believe to exist in nature. We have good reason for believing that the interior of the earth is much warmer than the crust upon which we live. Measurements have determined that for each centimeter we descend beneath the earth's surface, the temperature rises 0.00032° C. If this rate is continued far into the earth's interior, when we reach a point which is less than 1/10 the distance to the center we will have encountered a temperature hot enough at the surface to melt or vaporize every known solid. It is doubtful, however, if such temperatures are actually realized even at the center of the earth. These extremes are startling, but the earth is cold when compared with the sun and other stars. The sun is credited with a central temperature of 40,000,000° C. At such a frightfully high temperature no solid can exist, but

everything must be in the form of a dilute gas. The density of Betelgeuse and others of the giant stars is estimated as being about 1/100th that of our own atmosphere. Consequently the temperature upon the surface of such heavenly bodies must be enormously great. It is beyond the possibility of the human mind to grasp the significance of such a temperature range. We are impressed by such comparisons with the feeble results obtained in our best scientific laboratories.

One question concerning such matters demands an answer: How are such extreme temperatures maintained? It is believed that the liberation of subatomic energy is largely responsible for this vast amount of heat energy. We know that our atoms possess a very large amount of stored-up energy but we do not know how to liberate this energy or set it at work. This is a problem for the future to solve. It is very evident that the liberation of atomic energy will provide an enormous amount of power which may be set at work to drive the machinery of civilization.

What is the most extreme cold that has ever been reached?

The production of low temperatures consists in the removal of heat by various methods. The most familiar operation in which this process is carried out is in the freezing of ice cream. The mixture to be frozen is placed in a metal can, which is surrounded by a mixture of salt and ice in a cask made of wood. As the ice melts it must absorb large quantities of heat and since the metal is a much better conductor than the wood most of the heat is absorbed from the contents of the metal can. Temperatures 20° to 25° below zero Centigrade can be obtained by salt and ice mixtures. If solid carbon dioxide in the form of dry ice is used, a temperature of near −50° is obtained, and if a volatile liquid like ether is mixed with carbon dioxide snow, temperatures as low as −77° C. result. For the production of still more intense cold, gases are first compressed which cause a rise in their temperature, then they are chilled by some of the agencies already mentioned and finally they are allowed to expand, a process which requires the absorption of considerable heat. The apparatus includes a series of concentric tubes so arranged that when a quantity of the chilled and compressed gas is allowed to escape through a valve it will expand and absorb its heat from other portions of gas like itself. Consequently each portion of the gas that escapes through the valve is a little colder than that portion which preceded it. By this method one gas after another is changed to a liquid. Liquid oxygen boils at −182.5° C., liquid nitrogen at −195.8° C. and liquid hydrogen at −252.7° C. If these extremely cold liquids are allowed to boil under low pressure, heat must again be absorbed and the liquids become still colder and may be solidified by such treatment. Of all gases helium requires the lowest temperature for its liquefaction. Liquid helium has a boiling point 268.9 degrees below the freezing point of water and solid helium is given a melting point of −272.2° C. This is the most extreme cold that has ever been recorded in a laboratory. It is to be observed that it is 0.8° above the mythical point known as the absolute zero. From a consideration of the methods employed to obtain these extremely low temperatures it is evident that an artificial temperature which is lower than the point at which all gases become solids will be extremely difficult to obtain. There are also scientific reasons which justify the conclusion that lower temperatures will be almost or quite impossible to reach by present laboratory methods. As a result of this situation the temperature of −272.2° C. is the lowest one of which we are now certain and it is possible that this will remain for many years the nearest approach to supreme cold.

Some estimates of the temperatures to be found in interplanetary space have assumed that the degree of cold which exists is many times greater than any artificial condition which can be produced upon the surface of the earth. More conservative estimates make it seem likely that these temperatures are not lower than $-150°$ C. If this estimate is at all reliable then the conditions produced in the laboratory approach much more closely to that theoretical condition which may be described as representing the entire absence of heat.

What is the most costly substance known to commerce?

The nations of the earth are so accustomed to expressing commercial values in terms of gold that the expression "it is worth its weight in gold" is used to describe objects which are priceless. In attempting to find the most costly substance it is evident that we must confine our attention to articles which are bought and sold in the open market, eliminating everything which owes its attractiveness to its artistic setting, its association as a relic, its scientific value alone or any condition which materially disturbs ordinary exchange values.

There are several materials which are worth more than their weight in gold. All six metals of the platinum group are more valuable than an equal weight of gold. Under normal conditions platinum itself is about three times as valuable as gold, while iridium, the most expensive metal of the group, is worth nearly 15 times its own weight of gold. Among the most precious materials of commerce is the diamond whose value is influenced materially by its size, color, clearness and freedom from flaws. Accepting as an approximate market value the retail price of \$400 per carat, this gives the diamond a retail value of \$62,500 per troy ounce. The current quotation for refined platinum is \$40 per ounce, so diamonds at the present time are worth more than 1,500 times their own weight in platinum or 3,000 times their weight in gold. It is a remarkable fact that in the course of the business depression the price of diamonds as well as the quantity marketed has changed much less than other materials which are classed as luxuries. As a result of this peculiar trend in market conditions, platinum has fallen to about half its 1928 price, while diamonds have decreased only about 10 per cent.

The most costly material which is sold in the open market is radium and substitutes for radium, of which mesothorium is the most important. For many years the price of radium was in the vicinity of \$100 to \$120 per milligram. With the development of the wonderfully rich deposits in the Belgian Congo the price was cut to \$70 per milligram. This price was evidently selected for the purpose of stifling competition, while at the same time it brings enormous profits to the producers. It has been estimated that the profits in the sale of radium at the present rate amount to well over 1,000 per cent. Such greed is difficult to understand because these huge gains are made possible only through the suffering of victims from the dread disease cancer. There is no question concerning a material relief for many cancer patients if radium were available at a more reasonable price. In spite of this fact the enormous profits are realized from the sale of radium at a price which corresponds to more than \$2,000,000 per troy ounce. This means that radium is worth more than 100,000 times its weight in gold. It is by far the most precious article of commerce which we know. Second in order would be mesothorium, a material much like radium and usually sold as a substitute for radium. Its price is roughly \$1,500,000 per ounce, which is sufficient to command respect even in times of marvelous prosperity.

THE DIFFUSION OF SCIENCE[1]

THE NATURAL SCIENCES

By Dr. ROBERT A. MILLIKAN

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Mr. Toastmaster and gentlemen: I take it that the purpose of this gathering is to take account of stock in an enterprise which has been under way for about eleven years with a view to seeing what can be done to improve the job that is being done. Dr. Welch a moment ago inadvertently called this enterprise Science News, but its real name is Science Service, and it is chiefly in the distinction between "Science News" and "Science Service" that I find the subject for my remarks; for the name Science Service was very carefully and very appropriately chosen with full understanding of what it meant. I will come to the explanation of the difference in just a moment, but first a word about possible types of improvement.

There are just two possible ways of improving Science Service. One is by correcting defects which may have appeared in the eleven years of its life, without altering materially its general scope and plan, and the other is by extending its activity into new fields; and what I should like to comment upon first is the reason that Science Service has thus far been limited in its activities to the natural sciences.

Twelve years ago Mr. Edward W. Scripps asked a very small group of men to come down to his hacienda near La Jolla, California, to talk with him for a couple of days about his project of devoting a certain amount of money which he had at his disposal to this purpose. The men who were there were E. W. Scripps, his son Robert Scripps (who is here to-night) and other members of the family and Drs. Ritter, Hale, Noyes and myself. Mr. E. W. Scripps outlined what he had been thinking about and I think that Robert Scripps will agree with me when I say that the prime thing that his father told us he had in mind was constructive service to humanity, not mere news gathering. He thought it was possible to move our civilization forward by some plan whereby a knowledge of the method and the results of scientific study, particularly in the fields of the social sciences, could be spread among the masses of the people. We therefore chose the name "Science Service" as embodying in the smallest possible compass exactly the idea he had in mind.

A large fraction of the first day of our conference was spent in trying to analyze the relations between the fields of the social sciences and the fields of the natural sciences, and the net result of that discussion was that we persuaded Mr. Scripps that his object would be better served if we left the field of the social sciences entirely out, at least at the beginning of the activities of Science Service, and confined its activities to the natural sciences. That may seem to some of you here to have been a narrow view-point, but stop a moment before you draw that conclusion.

What he was after was improving the conditions of human life and not the spread of news as such, *i.e.*, it was not primarily a news-disseminating service that he had in mind. It was much more fundamental than that. And the question that was then discussed was what the dissemination of scientific informa-

[1] Addresses at the Science Service dinner in Washington on April 27, 1932.

tion in any field of science, social or natural, has to give to the improvement of human life—and before we had finished we had all agreed that the great thing that it has to give is simply an understanding of the scientific method. The day is gone by when any new discovery in science, social or natural, is likely to revolutionize human life, at once, at any rate. In fact, in general, the most outstanding discoveries in the natural sciences, however useful they may ultimately prove to be, create for the time being certain difficulties, because they force mankind out of its accustomed ways of doing things, out of its accustomed organizations, and any such change in the habits of a people is attended by difficulties and readjustments, as everybody who has lived through the last three years knows full well.

The great fundamental thing that science has to give is a method, and that method has been applied most conspicuously, though by no means exclusively, in the field of the natural sciences. What we call now the objective method, or the impersonal method, or the scientific method of getting at the facts without forming any conclusions beforehand, without starting with any preconceptions as to where we are coming out—that is the thing that began to get into human life in a conspicuous and pronounced way with the advent of modern science. In a very real sense this method got started about three hundred years ago. It is this that differentiates modern knowledge from the knowledge of the ancient world, which started with certain "a priori" assumptions or assertions about the nature of reality, and tried to fit phenomena into such a general philosophic scheme. All ancient philosophy did that primarily, although I know there are some exceptions. But the thing that differentiates the modern method from either the ancient or the medieval methods is that it definitely abandons all attempts at a complete synthesis of knowledge, built up into any philosophic scheme, and starts by trying to get at definite facts, and then allows these facts themselves, with their inevitable consequences, to determine the direction in which conclusions are formed.

And I think all men who know anything about the natural sciences will be in agreement that that method, which has now come to be called the scientific method, for the reason that it started in the natural sciences, is the thing that must spread, as of course it is spreading, to all the fields of knowledge. The social sciences, if they are going to succeed at all, must of course have the same objectivity as the natural sciences. Not only that, but if we are going to have a civilization which is built up of states which are self-governing states, democracies or republics, there must be a spread of the understanding and use of that method throughout the whole of the population, for the life both of the individual and of society is completely modified by it. But it is as yet the natural sciences rather than the social sciences that lend themselves best to the demonstration of the value of this method. For in the natural sciences we have actually, up to the present time, developed a basis of non-controversial fact. In the field of physics, to take a particular illustration, any well-written text-book of the year 1890 is a perfectly good text-book for to-day. The bases of physics have not altered at all, and any text-book of physics which soundly presented the knowledge of physics as it existed in 1890 can be used without changing a word to-day. You may introduce now, if you will, the idea of an electron, which you did not introduce then, but you had then everything that was essential in the idea of electric currents, positive and negative; and the whole of the knowledge that we had in 1890 is actually the basis of our modern

physics. All of it has practically universal acceptance to-day. No good text-book writer of any period ever allows his speculations to go beyond the range of verified facts. That is why the good text-books of 1890 can be used just as well to-day as they could then.

That is also true in all the natural sciences, for each of them has its body of non-controversial fact. This is certainly true in chemistry, and future chemistry will simply build upon that base of to-day's acquired knowledge. That is true in biology, as I understand biology, and it is also true in the geological sciences.

Actually, then, the main thing that the popularization of science can contribute to the progress of the world consists in the spreading of a knowledge of the method of science to the man on the streets and in giving to the public practical demonstrations of the results of that method of approach to life's problems. The natural sciences are at present enormously better adapted to do that than are the social sciences. Take one or two illustrations from the biological sciences. The germ theory of disease, the theory of immunization, etc., these are now supported by non-controversial facts. Yet the average man scarcely knows it yet, else how could he possibly pass anti-vaccination laws and similar absurdities. But as the masses actually come to see what has come out of this scientific method, as applied to the natural sciences, I have faith to believe that their whole outlook on life and their whole mode of approach to their own problems will change. What science has got to give, then, is primarily a method; and the way that it can do that best is to make the public familiar with what that method has accomplished.

One further point about method. When we scientists present the fields of the natural sciences in public address, I think there is a technique which practically every man uses, and which too we use in all our classrooms. It is this: We outline first where we have got to-day in the development of a field of recognized knowledge, *i.e.,* in the basis of fact which is not controversial. And then we move on into the controversial fields and say: "This is a view which is held by some; and this is a view which is held by others," the point being that we always start from the things on which we can agree.

Now, when we devotees of the natural sciences talked to Mr. Scripps, we felt at that time, at any rate, that it was pretty hard to find that basis of accepted fact in the social sciences. Personally, I have always believed that there must be such a basis of non-controversial fact in the social sciences. Of course there is in the field of history. But I will say that in the last two years, when I have been trying to listen to radio talks on economics, and when I have heard my banker and economist friends talk, I have wondered where the agreement was—there are such wide differences of opinion. They do not seem to start from a common basis of recognized knowledge at all. Let me illustrate what I am trying to say as follows. If we divide a given field of knowledge, such as physics, or economics, into two parts, the non-controversial part and the controversial part; then the non-controversial part in physics is an enormously larger part or fraction of the whole than is the non-controversial part in the field of economics. In physics the controversial part will be a little fringe on this whole body of knowledge, while in economics and politics it seems to me, from hearing my economist and political friends talk, that the controversial part is here the main body, and the generally accepted part—if there be any at all—is the fringe.

Now in either field it is this controversial part in which you find what is generally called news; so that if Science Service is to become merely Science

News it will not be of very much value, for it does no good to introduce the non-technical public to the regions of knowledge in which the best informed are still wandering in a maze, as yet unable to arrive at practical conclusions. However, I should think it might be perfectly safe to expand our activities somewhat into the fields of the social sciences, provided only the men who speak on these sciences would be much more careful than many of them are now, themselves to follow the method that I have described above, *i.e.*, provided only they would arrange their material so that they can say, "All this is recognized fact to-day by economists: here only is where we differ." But after all what the public needs is that part which is recognized fact, that part upon which it can depend and which it can surely take as its own starting point. And what I need, as a physicist, in my study of the political and social sciences, is to find what is that basis of recognized fact. I confess that, as one of the masses—for in this field I am just that—I find it terribly hard to find what the recognized economists and financiers and political science specialists agree upon.

And there is another thing. As soon as we begin to make news in this controversial field we run into a very grave danger. Let me illustrate by the matter of the tariff, which everybody knows has not been handled up to the present by any scientific method. If we begin to express opinions in that field we are running a very large risk of arousing a wave of popular prejudice against this whole scientific movement and thus of undermining the whole structure upon which and for which Science Service exists. Popular psychology is a strange thing, but a thing of enormous importance, as every banker knows to-day to his sorrow. The way in which the whole financial situation of the last three months has developed—my banker friends say it is just a matter of psychology—is a warning of the dangers we might encounter in this field. Science Service could ill afford a "run on its bank." You can play with those things, but if you are not careful you may produce a wave of prejudice against the whole scientific method which may do very, very big dis-service instead of service to human progress, which is, after all, the thing that Mr. E. W. Scripps was primarily interested in.

In spite of all this I want to say that I can not believe that the social sciences will not be able to develop a basis of recognized fact; I must believe that they are going to get it in the course of time, but until they have come nearer to it than they are at present, the safer and the better way for Science Service is, I think, to stick to its last, as Dr. Keppel said this afternoon, and to do the thing that is not fraught with so much danger of getting the whole effort knocked in the head. It would be most unfortunate if we got into a social-psychological situation where prejudice would determine action. When the storm was over there might be nothing left of Science Service. These were then the reasons that we gave to ourselves and to Mr. Scripps in 1921 for not including the social sciences in our program, and they seem to me to be equally cogent to-day, though it is greatly to be hoped that they will not remain so indefinitely.

I shall then devote the remainder of my time to-night to discussing the question of what can be done in the way of rectifying defects in Science Service and in making improvements along the lines in which it has been thus far working. From what has preceded you will not be surprised to hear me say that the first thing to do is to see if we can get away a little further than we are at present from our enslavement to news, as such. Science Service has already soft-pedalled news to a certain extent. I should like

to see it go even farther. I know the public wants news, and you will of course have to give it a certain amount of frosting of that kind, but the real cake is not in the news. Dr. Abbot this afternoon struck a note which I want to repeat. Science Service has been getting out certain phonograph records. That is not a news service at all, but it is a very important scientific service. I was unfortunate enough to have to make one of those records myself. Now anybody who is obliged to talk on any subject for exactly five minutes, and to say something worth while, must obviously weigh every word that he uses; weigh it not only with reference to what he thinks he is saying, but also with reference to what this big audience that is going to listen to it thinks he is saying. What we say to the whole world is not what we say in our scientific articles to our friends, not at all. In other words, in writing for the general public it is the emphasis and the implications that count; and I am talking now not to the reporter-men who write up the news; they are not guilty. It is the scientist who needs a training along that line; and I think myself that the effect of the Victrola record and the effect of the radio broadcast is a very wholesome one for us scientists. The necessity of giving a radio speech is one of the finest and most wholesome of influences that could be exerted upon a scientific man, or upon any intellectual man. For you can not do any extemporizing before a radio microphone; you have got to have every word written and you have got also to see that your statements not only are correct but that their implications and the interpretations that the public is going to put upon them are correct, in so far as you can make them so. The most important influence that the radio has had upon modern life, in so far as the education of the masses is concerned, arises, in my judgment, from the reaction that it has upon the men who have to do the broadcasting. It is bound to make us more careful, not about what we think we say, but about what we think that our audience is going to think that we have said. We have had enough illustrations of the difference between what a man thought he said and what the public understood him to say. You men who remember the war can well remember certain phrases that got going that were meant all right but which were taken differently from what was intended. The public did not understand them in the way the man who talked them understood them.

So it seems to me that an enormous improvement in the values of Science Service can be brought about by a more careful cooperation—and I am talking mostly to the scientists—between the scientist and the man who reports for it, more care being taken by the former to put his material into better form, to see to it that the phrasing is carefully done.

To take a simple illustration. The other day I had to make a little address at the academy, and some of the newspaper men said that my "conclusions" were such-and-such with respect to neutrons and protons. I did not say anything about my conclusions being such-and-such. I stated that *the evidence* from these observed facts was favorable to a certain hypothesis rather than to another hypothesis. These two statements are quite different things—I simply said, "This is evidence on one side"; but it is a long way from presenting evidence to drawing conclusions, as much so in physics as in a court of law. The evidence must not be confused with conclusions.

One other thing that I would like to suggest as a basis for improvement. I want, if I may, to pay a little compliment to the paper (the *New York Times*), a representative of which you are going to hear in a minute, because of the fact that it takes so much pains to present so many scientific addresses

and reports in full. I do not mean to urge the printing by newspapers of long articles. There are very few of them that are worth it. We scientists write articles which no paper ought to publish in full. But if you science reporters will force your scientific man to write his own abstract; and will then quote it without rewriting it, a great step forward will be taken. I don't object to your rewriting a part of it, if only the public will understand what is your rewrite and what the author himself said, and what I myself want to see is what the man himself said. If you can get that in some short form, and if your newspapers can in general be induced to print "the words of the author," with or without your rewrite, but anyway the words of the author in just the form in which he wants them presented, I know, and every good newspaper man knows too, that you are going to get an audience that you do not get now, because there are a lot of people who want to know just what the author himself said, not what somebody said he said, not what somebody inferred that he said or wanted him to say, but what he himself said. If Science Service can do a little more of that it will take a big step forward in perfecting the humanitarian and the scientific service which it exists primarily to render.

There is one other point that I want to mention. It seems to be the effort of all news agencies to find out from scientists, not what they have done but what they are going to do, to get into their laboratories and find out what their plans are. I would like to see all that soft-pedalled, because it has no value whatever. It only annoys the scientific man. He does not want to state what he is going to do because he does not know what he is going to do. He does not want to be forced to say what he is going to do and there is not any value in it if he does yield.

Again, I want to call attention to a thing that Dr. Abbot mentioned this afternoon. Science Service is to be congratulated in that it has camouflaged under the item of news a lot of first-class stuff that has been known a hundred years or two hundred or fifty years. That is what the public ought to have. That is what the public needs, because it is a body of recognized fact that the public is ignorant about. If it were not ignorant about it, you would not have anti-vivisection or anti-vaccination campaigns. It is because the public is ignorant of the facts as to what vaccination has done that it is possible for such political tommyrot to get started as sometimes does get started in California and also in other states.

Then there is one other point. I am far from criticizing the average man who is sent by a newspaper or by Science Service to report the news. He is obliged to report the news. He has to report what we are saying. And in general you reporters do it extraordinarily well; I am often amazed at how well it is done. In fact, around our place there are a couple of reporters that I do not have to watch at all—they do it so much better than I do. They know what things are permissible and what things are not permissible and I can trust them completely. But, in general, if the reporter would be willing to sit down with the author and let the author see the way he writes up the material—and let the author OK it—it would save many mistakes. I am well aware that Science Service does this in many cases. I congratulate you on it and want to see the practice enlarged.

A few of those things would help a lot toward the improvement of Science Service.

THE SOCIAL SCIENCES

By Dr. HAROLD G. MOULTON

PRESIDENT OF THE BROOKINGS INSTITUTE

It has long been a favorite pastime in academic circles to discuss the relative importance of the natural and the so-called social sciences. Which is more fundamental, or basic, in character? Which has contributed more toward the upbuilding of our civilization? Which has greater significance to-day, and about which is it the more important for the public to be reliably informed?

It is not my purpose to attempt to answer these questions, for I do not think any important purpose would be served if they could be answered definitely and to the satisfaction of all concerned. I should like, however, to direct attention first to certain ways in which the natural sciences and the social sciences have reacted upon one another and how the two working together have contributed to the development of the economic system and the civilization of to-day. My emphasis at the start will thus be on the interdependence of developments in the various divisions of knowledge.

Without the discovery of certain natural laws and without the inventions based upon them the mastery which mankind has gained over nature would not, of course, have been possible. Instead of the highly developed civilization of to-day we would still have been in a stage of semi-barbarism. It is, therefore, strictly correct to say that without our achievements in the realm of natural science the epochal changes of the last hundred years would not have been possible.

It is also true that without man's capacity to devise economic, governmental and legal institutions capable of meeting the needs of a changing world, economic and social progress such as we have had would also not have been possible. At every stage in the evolution of the complex civilization of to-day the development of social machinery and institutions has facilitated and made possible advancement in natural science. I refer, of course, to the development of systems of government capable of maintaining law and order, to such legal institutions as private property and contracts, and to such economic institutions as money, credit and the corporate form of business organization. It is the development of these social institutions which has made possible the transformation of the simple economic world of the medieval era into the highly complex organization of to-day with its enormous productive capacity. Without these social institutions scientific discoveries would not have had an opportunity to bear fruit in a practical way. Thus advancement in the natural sciences has gone hand in hand with the evolution of social institutions; each is indispensable to the other.

It will be observed that in the foregoing statement I have not used the expressions "principles of social science" nor "laws of social science," but have stressed rather the development of social institutions—legal, economic and political. In this emphasis and this terminology I am giving expression to a point of view which is, I believe, essential to any adequate understanding of what the objectives of so-called social science should be, and of the importance of the dissemination of knowledge in this field to the further development of our civilization.

The fundamental concern of social science—using the term in its broader connotations—is the devising of agencies

and institutions which will bring continuous economic and social improvement, or, to use a phrase which has never been improved upon as an expression of the ultimate purposes of democracy, to promote the greatest good of the greatest number of people. We wish not only to understand the workings of the economic and social world, but we wish also to make possible its improvement.

In such a conception of social science there is obviously a place for the formulation of general laws or principles of human behavior and social progress; but not, in my judgment, a place of paramount importance.

I was very greatly interested in Dr. Millikan's statement that there has been comparatively little change in physics since 1890; and I was equally interested in his remark that he has been unable to discover, by reading certain current economic discussions of unsettled problems, any great body of doctrine upon which economists are in agreement. If Dr. Millikan had surveyed the fundamental text-books of economics in 1890 he would have found that there was a very large measure of agreement; and if he had gone back forty years further, to 1850, he would have found that there was almost complete agreement among economic students upon the basic principles of economics.

In brief, the history of the development of economics goes back to 1776, when Adam Smith first brought out his great treatise which became the foundation of political economy. There is no question that that book was conceived and written in the scientific spirit. It sought to lay down the fundamental principles that should be adopted and acted upon if we wished to promote the greatest possible wealth production for the people on this globe. That was followed by a series of treatises by English economists, culminating in 1848, when John Stuart Mill's great "Principles of Political Economy" was written. It was believed, not only by John Stuart Mill and his contemporaries but by most students of economics, in the Anglo-Saxon world at least, for the next twenty-five years that the last word on political economy had been written, that Mill's book had rounded out a body of truth built up upon the basis of certain facts and principles, or laws, as to human desires and conduct and as to the limited productive capacity of nature.

About twenty years later new light began to be thrown on certain phases of economics by a group of Austrian economists who approached certain aspects of the problem from a new angle. Then that was in due course followed by Alfred Marshall, who in 1890 brought out his fundamental treatise, which integrated the analyses of the Austrians with those who had gone before, in the English line, and showed how they could be substantially harmonized.

It was this accepted body of economic doctrine upon which economists of my generation were reared. A considerable part of this doctrine remains to-day, as any one can find by a perusal of general texts, as distinguished from the literature of controversial discussions. Nevertheless, there have been great changes in economic discussion during the last 40 years, and, as already indicated, the body of doctrine upon which there is general agreement is now smaller than was the case a generation ago. In the next stage of my discussion, I shall seek to show the forces responsible for this tendency toward unsettlement.

The change is attributable, as I see it, on the one hand to a growing body of statistical data that has given us a vast amount of factual material not hitherto available; and on the other hand to significant changes in the structure and organization of a rapidly evolving economic mechanism. It is the latter factor which I wish to discuss in the few moments at my disposal.

As a result of the economic and social evolution of modern times, we have to-day an economic system, or machine as I prefer to call it, of very great complexity and of most delicate adjustment. The managers of this system, or the drivers of the machine, are individuals who are not directly working together for a common goal but are individually in pursuit of private profits. Production will be carried on, the existing plant and equipment will be operated, and new developments will be undertaken, provided the so-called entrepreneurs can see their way to the making of a pecuniary profit. It is believed, and it has certainly been true over much of our modern history at least, that the incentive of individual gain promotes general economic progress.

This system involves large monetary outlays in the development of plant and equipment and in the production of commodities which are to be sold in the market for a financial price. If this price exceeds the monetary costs there is a profit; if not, there is a loss. In order to carry out production on the most efficient possible terms, it has been necessary to develop large aggregations of capital, and this in turn has required the evolution of the system of credit and of financial intermediaries between investors and the borrowing corporations. We have had, indeed, the development of a whole series of financial institutions which, taken together, comprise a financial system which, in turn, largely controls and organizes economic society.

This complex economic system, which tends to be world-wide in the scope of its organization and is, in consequence, handicapped by political organizations on national bases, is a most intricate mechanism. The machine never operates at theoretical maximum capacity. Measured in terms, let us say, of an eight-cylinder car, it runs on the average perhaps on the equivalent of five cylinders—sometimes operating on seven and at other times on as low as two or three.

Why is this? What forces or conditions, or perchance laws, continually impede the operation of the machine and at times produce the violent fluctuations with which we are all familiar? To find the answer to this question and to remove the cause, or varied causes, as the case may be, is as challenging, as difficult and as important a problem as is to be found in the entire realm of science. The ascertainment of the source or sources of friction and the suggestion of means for their elimination require intimate knowledge of business processes and of the working of financial and other economic institutions. The economic scientist must give the most minute study to the various parts of the complex mechanism and also to their interrelated workings. Such studies involve the assembling of all pertinent facts and also the interpretation of their significance. The method is rigorously scientific—however much the procedures may differ from those of the physical laboratories.

Now the old economics, the economics which had come to be regarded as settled, the economic "truths" of former times, had substantial validity under the conditions of a simpler age. But under the conditions that exist to-day a considerable part of these principles are no longer adequate. The economic structure has changed so rapidly that the entire problem of economic analysis has been profoundly altered. We are concerned with very rapid organic evolution.

I may perhaps best reveal how complex this problem of social science is by reference to a particular investigation with which the Brookings Institution is at the present time concerned. We have raised the question as to whether the explanation of the failure of the economic machine to operate normally at

full capacity may not perhaps be found in the way in which the wealth and income of society are distributed among the different classes of the population. The perplexing economic phenomenon with which we are all more or less familiar at present is the simultaneous existence of great unused productive capacity and an army of potential consumers who because of unemployment are without purchasing power. The dilemma may be expressed as follows: Industries can not produce at full capacity unless they can sell greatly increased quantities of goods to consumers in the market; consumers can not buy greatly increased quantities of goods unless more adequate employment and higher incomes are provided. We can not produce more until we can have more consumption; we can not have more consumption until we produce more, that is, until the consumers are furnished the purchasing power that is given to them only through the productive process itself.

An existing capacity for production greatly in excess of market demands is a state of affairs which had not been anticipated by most students of economic development. In the earlier days, during the greater part of the 150-year period since the formal study of economics began, the great problem appeared to be that of increasing production, through the building-up of capital equipment. It was believed that the consuming power would expand in direct proportion to the expansion of production, and that the greatest progress would necessarily follow from that economic system which promoted the most rapid saving and development of capital goods. It was argued that the increased supplies of capital goods would automatically decrease production costs and prices, and that the resulting increase in real wages, resulting from falling prices, would enable the masses of the people always to purchase the increased quantities of goods turned out. According to this theory, the fundamental motivating force was the expansion of capital; the increase of capital goods came first, and increased consumption automatically followed. That this result has not been fully realized is suggested by the maladjustments to which reference has already been made.

In view of this situation, we must inquire whether recent trends in the distribution of wealth and income in society may not perchance serve to retard economic progress. We are confronted with a certain body of known facts which suggests this hypothesis. What are such facts? Well, for one thing, we have found that the periods when capital expansion and growth are most rapid are precisely the times when the volume of consumption is greatest. Always a period of extravagant consumption has, according to the factual records, been a period of rapid capital expansion. Now, that suggests a possible interrelationship between expanding consumption and expanding capital creation.

We have also found that with the development of the modern corporation a very large amount of capital savings occurs automatically—through the setting aside of a portion of the income in the form of surplus and putting it back into the business. The corporation has thus been an agency which automatically results in a rate of saving much more rapid than was formerly the case.

Another element in the situation is that as society has become more wealthy we have larger groups whose incomes are in the higher brackets. Those whose incomes are in the higher brackets do not —we believe the facts will show—spend as large a percentage of their income for consumptive goods as do those whose incomes are in the lower brackets.

The question therefore arises: Are we, by virtue of the changes that have occurred in our economic system, now getting new capital, developed faster than

we are increasing the effective demand for the products of that capital? Have we thus been thrown out of balance in the rate of capital expansion as compared with the rate of purchasing power expansion in the hands of the masses of the people? We believe it is possible to find from the data available the answer to this fundamental question.

We would next inquire whether, if a larger share of the nation's annual income went to the masses of workers, both urban and rural, the resulting expansion of consumption would serve to stimulate more rapid economic growth. If this hypotheses (which we state merely as a hypothesis) should prove to be correct, then it would appear to follow that a wider diffusion of wealth and income would prove of direct benefit to all classes of society, including those in the higher income classes as well as those in the lower income classes—because the machine itself would then work more continuously near maximum capacity. By carefully analyzing the trends as to capital development for the last thirty years and the distribution of wealth and income, we hope it will prove possible to give a fairly definite answer to the fundamental issues that have been raised.

That is a problem that vitally concerns all classes of people, a problem which has arisen because of the changing organization of society. It could not have been analyzed on the basis of any facts available in a former era. It must be studied in the light of existing conditions and of the data that are now available. That the project as conceived is scientific in the best sense of that term can not be gainsaid.

Aside from these basic considerations of the working of the economic system as a whole economics, like every other general division of knowledge, is concerned with a great number of special problems, and each of these requires special study by trained investigators. We must first and foremost have intimate knowledge of facts and processes, and then we must interpret these in relation to objectives that are conceived to be socially desirable. Nearly every question that comes before our legislative bodies involves economic issues of far-reaching significance. They can be answered only in the light of accurate factual data and knowledge of economic and financial processes.

Under our system of government there is, of course, little opportunity for our legislators to be informed on the economic issues about which they have to frame legislation. This is due to many factors which are perfectly familiar to you all. It is in part attributable to lack of adequate training in economic analysis, and in part to the fact that they must constantly give heed to the ill-formed views or special interests of their constituents. Society's hope of success in solving the many problems with which it is continuously confronted thus undoubtedly rests in a very fundamental sense upon the dissemination of the results of studies in the social sciences conducted by individuals or agencies which are entirely free from political or economic coercion.

Now we have all sorts of so-called economists: we have economists for the Carpet Manufacturers' Association; we have economists for the agricultural cooperative soieties; we have economists for the Forestry Association. We have economists for the American Federation of Labor. We even have recently organized an association of "practical economists," who proceed at once to concern themselves with issues of a highly theoretical character. Those people are, however, not economists. Generally speaking, they are economic attorneys working for a special interest. I do not object in the slightest to economic attorneys. But it is a part of the problem of Science Service, if it is to carry to the public generally the results of scientific investigation, to differentiate between

those who are working in the pursuit of some special interest and those who are working on an entirely objective and independent basis. You will be interested to know, Dr. Millikan, that I was once referred to as an "objective" economist, but the individual who made the reference went on to define an objective economist as one who was in pursuit of a definite object.

Referring more specifically to Science Service, in which I have been interested for a number of years, it does seem to me possible that a certain type of information bearing on the social sciences can advantageously be disseminated through such an agency. I see no reason whatsoever why Science Service could not take any given article or any given book and say, in the first paragraph:

Here are the qualifications, training and experience of the man who wrote this book. Here are his connections. If he is connected with a labor organization, let us say that he is connected with a labor organization; if he is an economist for a lumber manufacturers association, let us say that he is an economist for a lumber manufacturers association; if he is connected with a bank, let us say that he is the economist of the X National Bank; if he is connected with a research institution or an independent organization, let us say that he is connected with that research institution or independent organization. Those are the facts about the author.

In the second paragraph there might be a succinct statement of the investigation made by this individual, the methods that he has followed, and the conclusions at which he has arrived.

The method suggested is one which would convey to the average reader certain definite information as to the conclusions reached by scientific investigators. I believe that it would promote useful thought in the mind of the average reader. I think it would give him something of the scientific spirit of which both Dr. Millikan and Dr. Welch have spoken. I would like to see Science Service experiment in the field of the social sciences. If it does not go into the social sciences sooner or later it will be evidence, not that there is not a spirit of science pervading the ranks of social scientists, but that Science Service itself lacks confidence in its own ability to sift out from the field of social science those works which are scientific in character and those subjects which lend themselves best to popular presentation. My judgment is that it will be a reflection upon Science Service in the long run if Science Service does not embrace its opportunity in the field of the social sciences.

THE PRESS

By JOHN H. FINLEY

ASSOCIATE EDITOR OF THE NEW YORK TIMES

Mr. Chairman and gentlemen: Dr. Millikan is to give an address in New York, I am told, to-morrow afternoon, on the subject of "Time." I do not know what his definition of time is, or whether he speaks on standard time or daylight saving time, but those of us who are here are under the restraints of one or the other. I call your attention to the fact that it is now 12 o'clock by my time as I began to-day; and I hope that no one will feel under any constraint to stay while I finish the address which I prepared to give. I will make it as brief as I can.

I was over in Greece some years

ago. After I landed I was informed that I was to represent the colleges and universities and learned societies of America at the dedication of the Gennadius Library, which was built by the Carnegie Corporation of America, and the next morning I started to Delphi to consult the oracle as to what I should say, and I heard in my meditations this voice from the oracle, as I recall it:

Boast not of towers (for thus did Babel boast)
Nor wheels (Ixion's fate is now as then)
Nor Sisyphan statistics upwards roll—
Before your Agamemnons there were men.

But I am distressed now not so much in remembering the Agamemnons that have been as in the presence of these Agamemnons of science who are here before me. In my earlier days I might have said as Omar Khayyam:

Myself when young did eagerly frequent
The Ph.D's and heard great argument
About and about; but evermore
Came out in doubt yet wiser than I went.

As one who, once included in the class "educator," has recently become a member of that group of chroniclers and augurs of the day, observing the flight of events in all the skies of the earth, and who seems to some to have fallen, like Lucifer, from a high estate into one which has no higher place than the fourth, I venture to say a word on behalf of my fellow journalistic historians, historians of the present tense—those luciferous writers who are scattered over the earth from darkest Africa to luminous Boston, from Greenland's icy mountains to Mother India's coral strands. They are like the crustacean creatures to whom the Princeton scientist has given the name Luciferin, and so redeemed the name Lucifer from its Miltonian doom, which, though it seems a bit of fallen star dust, gives the utmost light without heat—a name that will some day be appropriate for the entire press as an agency of light without heat which only the lucifugous (those who love darkness rather than light) will shun.

Balzac has called journalism "the religion of democracy" and the journalists the priests of democracy. I do not know just what he meant—except perhaps that democracy daily turns to the press, to the newspaper, as an instrument essential to its highest functioning.

If journalists are priests, they are priests after the order of Melchisedek, that is, having "neither beginning of days nor end of life," for they live in the eternal Einsteinian present, ever on the outer verge of the "continuum." I repeated in the presence of Dr. Einstein a few weeks ago a definition of a "continuum" and, as he seemed to approve it—though I don't know whether he understood it or not—I dare to repeat it: "The continuum of events exists as a background for phenomena and when happenings occur in any region whatsoever the events are there ready to give forth their testimony."

But unless the journalist is there to hear what the events have to say, it will be buried so deep by the succeeding events that even the historian of the past is liable never to find it except with the help of the archeologist.

The true function of the historian was defined two thousand years ago by Polybius, who said that it is "to record with fidelity what was virtually said or done, no matter how commonplace it may be." That is the definition of the function of the true journalist, with a change of tense only, and with the added responsibility of giving it its setting or relationship, and to do this he goes to what is called in the newspaper office the "morgue" for his material, *i.e.*, the clippings from the newspaper of yesterday —which become the history of the imperfect past, not the perfect past, but the imperfect that comes up to him every moment of the present and goes on living

and loving and striving. The journalist is not a mere stentor but an interpreter, an all-round man of this universe of universes, whether it is expanding or contracting, running down or winding itself up.

And, as history is no longer a narrative of the doings only of kings and statesmen and prelates and generals, but reports the activities, mental and otherwise, of scientists and poets, merchants and artisans, farmers and explorers, students and vagabonds, so is journalism, the religion of democracy, all-embracing; it is the continuing revelation and record—daily, weekly, monthly or yearly—of the Almighty's continuing revision of the earth which is not complete, as the earthquakes and droughts and floods testify, and of His daily dealings with the sons of men.

I do not claim for the newspapers that they are inspired and written by holy men as of old, but merely that the best of them try to continue the objective record, news, though I think no reporters have been found quite comparable with the man who reported the Creation, and no editors who have improved on the Sermon on the Mount.

The editor's prototype is Isocrates, son of Theodorus. He was called "the old man eloquent" of his day, though he never made a speech. He wrote his speeches and circulated them on a small scale as the editor does on a larger scale to-day. Or, perhaps better, a prototype of the ancient Democritus, who, despite the range and seriousness of his thought, was called the "laughing philosopher." Here is a condensed summary of the attainments of Democritus:

> He was abreast if not in advance of the astronomy of his day, he had traversed the greatest part of the known earth, he wrote a treatise on navigation, he was learned in physics, writing on the magnet, the rays of light and the water-clock, he was fond of music and poetry, leaving works on rhythm and harmony and the beauty of epic poems, he was a critic in the matters of art, he left a book on fevers, another on prognostics, another on pestilences, another on the right of way of living, and besides wrote authoritatively on agriculture, tactics, the principles of laws, the calendar and colors, ethics and cheerfulness, besides being a zoologist, anatomist and psychologist.

But it is an even wider range than Democritus, or even Aristotle, that the modern Democritus, the editor, must have. He must not only have a glimpse into all fields of human knowledge and achievement; he must know the way to the verge in some one subject—to the place of the burning bush behind the mountain. As Charles Dana said: "He must know whether the theology of the parson is sound, whether the physiology of the doctor is genuine, and whether the law of the lawyer is good law." He must also be aware of the great abysses of human ignorance which no editorial Marcus Curtius can close, however sacrificially noble his purpose may be. He must not only know something about everything, but know where to get the everything that is known about anything.

But he must not only know, he must be able to tell what he knows or get intelligibly told what others know but can not tell. Professor Gildersleeve, the great Greek scholar, once said that there was need of academicians, but he added that they must forget their academic business if they wished to reach a wide public. He also intimated that there was certain advantage in being obliged to write at what he called finger speed, for the best words come to the front under such conditions, that is, if one has the best words to begin with. That was before the days of the typewriter. It is important to acquire, and acquire only, a vocabulary for such emergencies, and if anything is to be said for the cross-word puzzles which have lately infested the press, it is this.

As an "educator" I was accustomed to divide those who could not or did not

tell the truth into three classes, not into four, as did the ancient Persian or Talmudic wisdom: First, those who do not know the truth and so if they tell it, they tell it only by accident; second, those who know it but are not willing to tell it; third, those who know and wish to tell it but do not know how.

Since I have become a journalist, I find in the observation of my fellow journalists that not even a research professor is more eager to know the truth or more eager to tell it than they—and I find too that the journalist is usually much better able to tell the truth than the research professor because he knows how to speak to the ordinary mind.

As you have already said, sir, the newspaper must know the truth, as fully as it can be known, be ready and fearless to tell it, and then know how to tell it. It is more and more to be a newspaper presenting the facts rather than opinions, and less and less an organ, but necessarily appraising news in its wholesome human values—for, as Vernon Kellogg said some time ago in an article (in *The Atlantic,* I think it was) on "Biology and Death," the biologist has to do with the species and the ordinary observer has to do with the individual. That is why, he said, the daily newspaper informs, fascinates, thrills us, while the biologist's information leaves us cold.

Dr. Keppel once called my attention to a book by a recent English essayist that put forth the theory that Nature thought to achieve the Creator's purpose by gathering as many cells as possible into one body, to be controlled by a single intelligence. But this resulted in the development of the giant lizard or the monster pig, the Dinosaur, the Baluchitherium, which perished because such mighty aggregations of cells could not adjust themselves to changed conditions or conquer them. We have now but the fossiled remains of these creatures—"fossilized failures." Then Nature set out, under divine compulsion, to reach the perfection which it sought ultimately in man, through an infinite number of individuals associated in the swarm, the flock, the herd, the tribe, the clan, the nation—may I say the League of Nations—looking toward the unity of mankind—attaining through society what the individual may not alone achieve. In that evolution the newspaper becomes a prime agent—for it can be carried forward only through the perfection of communication and interpretation.

And increasingly science's wisdom must find a place in that news, else the vast herd of human creatures may meet, metaphorically at any rate, the fate of the lemmings of Norway, swarming down to a drowning death in the sea without any plan for their journey or prospect in the event.

Scientific progress to-day is so rapid and constitutes such real news that no paper can afford to ignore its contribution to human welfare. The press once paid little attention to such gatherings as those of the American Association for the Advancement of Science and the British Association. Now the proceedings of the important scientific and engineering societies are often fully and well reported.

Several years ago I recommended for the Pulitzer prize a man whose only submitted work was his report of a meeting of the American Association for the Advancement of Science, and he got the prize. I wanted in another year to have a man get that prize who reported the lectures of Niels Bohr at Yale when he was giving six lectures there on the structure of the atom. I believe that his theory is no longer accepted, but this man reported the lectures so well that the secretary of the Franklin Institute wrote me that he had never seen published reports in a newspaper of abstract science material equal to those.

Newspapers have been irresistibly drawn into the swirl of science. Their

editors sense that extraordinary changes are taking place as the result of research and they instinctively respond. What they need is the guidance of scientifically trained staff men, for it is rarely that a paper has as its managing editor a Democritus such as the best managing editor that I have known, who was prepared when the tomb of Tut-ankh-amen was opened to enter intelligently with the archeologist, who when Einstein propounded his theory had some notion of what he was talking about, whom I found one day trying to find geometrically the area of a triangle in the terms of its sides, who in the midst of the last Presidential campaign wrote a two-column editorial on the new planet, Pluto (which I wanted at the time named Minerva, since I thought it was too bad that Venus should be left alone with all those celestial wandering gentlemen). And yet he could tell you the baseball champions for the last ten years, or the Presidential returns for the last century.

According to Dr. Austin Clark, of the Smithsonian Institution, "the number of writers for the daily press who devote their time more or less exclusively to science has increased from three or four in 1921 to between fifteen and twenty now."

Organizations like Science Service unquestionably improve newspaper standards by revealing what is real science news. And I say this not upon my own authority but that of my scientific associate. No newspaper of to-day could afford to maintain a large scientifically trained staff to range over the whole field of scientific and engineering achievement. There are, I am told, 25,000 scientific and technical journals and periodicals in which science news first appears. Even a special organization like that of Science Service can not read and digest them all. But it can digest several hundred, as it does, and thus lighten the tasks of the newspaper editor.

From the other side, that is, from the side of the scientist, there has been a distinct change in the attitude of scientific men to the newspaper. Once they despised its efforts at popularization. Now they realize how necessary the newspaper is if science is to have any popular cultural value. We even find the American Institute of Physics established by a group of research scientists for the primary purpose of aiding the press to present the facts of physics simply and clearly. The engineering societies also have their publicity bureaus. The amount of scientific and engineering information sent to the *New York Times*—again I am told this by my scientific associate—spontaneously is enough to fill at least two pages daily.

I have but in the most general way suggested the opportunities and obligations and the service of the press as a medium for the distribution of scientific information. So far as science can speak with an authoritative voice and in language intelligible to the lay audience, the press will be its eager interpreter. (And I may say that a reporter never has any opinion; he simply reports the news and the editor is the interpreter.) It is confused at times by diametric views, such as those of the expanding and shrinking universe, but when science speaks with certitude and clearness, the press will become its amplifier to the eyes of the multitude and will even assist in the social and economic miracle of multiplying the loaves and the fishes for the hungry and saving life.

The best answer to those who find fault with our product in the present tense is given by a recent historian of the newspaper, Miss Lucy Salmon, who has said:

> With all its inaccuracies, its lack of proportion, its many temptations—not always resisted—to throw prismatic colors instead of the white light of truth on its accounts of the day, the periodical press still remains the most important single source that the historian has at his

command for the reconstruction of the life of the last three centuries.

And if for the last three centuries, why not for the passing day?

Mr. Justice Holmes once said in a letter to a friend of mine that we "no longer look to the past for our sanctions. A fashion in hats goes around the earth in six months and is forgotten in a year." We shall come to glory, he added, "not in immortality, but in illocality."

The press is the chief agency of illocality, assisted by those swift, modern mercuries of automobility and telepublicity, in this televictorian age, as I have often called it—the age of the telegraph and the telephone, the tele-radio and television, and above all the tele-printed word.

If we are to find and spread the best that anywhere comes to be in the present, those who are selected for this high service, as I have said, must know how to tell the truth, and they have to do it with words, in cold type. Dr. Samuel Johnson, the editor of the famous dictionary, quoting some one before him, said that he was not so lost in lexicography as not to know that words were only the daughters of men while deeds were the sons of Heaven. But, after all, it is only by the daughters of men that the sons of Heaven get born. In the "Terrible Meek," by Charles Rann Kennedy, the dramatist presents a scene in which a cross is dimly seen in the background and in the foreground an English Tommy and an English Captain are shown in conversation. The Tommy is saying that it is too bad that one should come to this just for the saying of a few words, "Words, words," said the Captain, "words are the most powerful things in the world. All the good or bad that gets done in the world is done by words." Truly, "in the beginning was the word," but it will be with man to the end of time, that is, until God stops speaking to men until the reporter journalist has filed his last copy and the editor has made his last comment, until the last edition has gone to press and Gabriel's trump has been heard by radio around the world.

THE NEW CONCEPTION OF MATTER IN MOTION

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THE physical world is like a puppet stage upon which we see the various phenomena of nature. The stars, the sea, the minerals of the earth, the living plants and animals and the products of our industries—these and the devices of the physical laboratory are the visible actors whose actions are controlled from behind the scenes by some secret mechanism. It is the guessing game of the natural philosopher to try to imagine what this mechanism is and how it operates.

Whereas men have been pondering over this riddle since the dawn of civilization, it is only within comparatively recent times that any real progress has been made in its solution, and though still very far from being completely unraveled, the marvelous success of the atomic theory in fitting together large blocks of the puzzle indicates that therein lies a clue to a general understanding of a large class of natural phenomena. The suggestion that matter is composed of indivisible particles or atoms dates back to the ancient Greeks, although in their hands it failed as a useful physical theory to account in detail for any of the observed properties of matter. In the middle of the nineteenth century the idea was again revived, and, at this time, it was developed into what is now known as the kinetic theory of gases.

According to the concepts of this theory, a glass tube filled with a gas under the pressure of the atmosphere is in reality the scene of an excited mob of similar atoms, rushing at each other with faster-than-rifle-bullet speeds, colliding with the walls of the vessel, each being jostled about by the onrushes of the others, and presenting to the eye of the imagination a scene far more wild and disorganized than the sea of taxicabs in Times Square on a Saturday night. The theory tells us that each atom is a tiny sphere only a few hundred-millionths of a centimeter in diameter; that it can travel, on the average, a distance of ten to one hundred times its diameter before colliding with another atom; that, in spite of the fact that one cubic centimeter of the gas contains atoms more numerous than the blades of grass on a huge putting green the size of all the territory east of the Mississippi River, their combined volume is only about one hundred-thousandth of the cubical contents of the containing vessel.

It would be impossible in this short article to enter into all the steps in the development of the theory of the atomic constitution of matter, but two observations will indicate how well the theory is in accord with experimental facts. If the spray from an atomizer is examined under a high-powered microscope the small drops of liquid floating in the air may be seen to dance about on highly irregular paths, darting first this way, and then that. Its motion may be compared with that of a football hero who is being tossed on the hands of a mob of admiring students. In much the same way the droplet is being knocked on all sides by the impacts of the atoms of the air, and since these are of finite size and number, it is a matter of chance that at times the drop will be bumped with more force on one side than on the other. The motions of the drop, produced by the im-

pacts of the atoms, are, in fact, a visible epitome of the motions of one of the atoms, the velocity and range being reduced in proportion to the greater mass of the drop.

Even more conclusive evidence than this for the atomic constitution of matter may be seen when the rays from radium are allowed to pass through an atmosphere supersaturated with water vapor. Under these conditions the rays produce a condensation along their path in the form of a visible thread-like cloud very much like the line of smoke left by a "tracer" bullet. These rays, shot out like the bullets from a machine gun, can be collected in a glass vessel, and, in their quiescent state, they constitute a gas which can be recognized as ordinary helium. Here, then, we have a vivid picture of helium atoms shot out from the radium, one at a time, and in their aggregate producing a familiar form of matter.

These are but two illustrations of facts which more obviously demand the atomic theory in their explanation. There are numerous other instances where the success of the theory has been equally great, not only in giving a qualitative explanation of the phenomena in question but in yielding precise numerical values which agree with such measurable quantities as the pressure of a gas, or the rate at which it flows through a tube. So extensive are these applications of the atomic theory that we may regard it as a proven fact that atoms exist, and that they play as important rôles behind the scenes of nature's theatrical performance as do the strings and levers in any puppet show.

Remarkable as these discoveries may seem, they are but surface scratches when compared with the deeper diggings into nature's secrets which the past two decades have witnessed. If a gas is stimulated by the heat of a flame or by the passage through it of an electrical discharge, it will emit light of various colors. This light is the voice of the atom, and the modern physicist has learned to understand its language. Just as the paleontologist reconstructs the animals of a million years ago from a few remaining bones, so the physicist reconstructs the atom from the colors of its light. The methods of the physical laboratory are capable of distinguishing between approximately four million different colors, and of these the hydrogen atom, as an example, emits only about one hundred. What a stupendous achievement of the mind it is that theoretical physicists have been able to construct in the imagination a mechanism which will emit exactly these one hundred colors and no others. A still more remarkable aspect of the situation is the fact that the mechanism which has been constructed to explain the atom's light also contains the properties necessary to explain such facts as the atom's tendency to unite with other atoms in the formation of chemical compounds, or to explain the distances at which atoms are separated when packed together in a crystal. Such confirmations of the theory as these give us confidence that the atom is as well known as any of the large-scale objects with which we are familiar in every-day life.

Of the ninety-two different kinds of atoms found in the earth's crust, the simplest is that of hydrogen. It contains a central nucleus which carries all but one two thousandth of the total mass of the atom and a charge of positive electricity equal to about one per cent. of the smallest charge required to affect our most sensitive charge-measuring instruments. Circulating about the nucleus is an electron bearing the small remaining fraction of the atom's mass and a charge of negative electricity equal in amount to the positive charge of the nucleus. The exact path described by the electron has apparently no way of making itself known to us, but its average distribution in the space about the nucleus may be

pictured from the accompanying figures (Fig. 1, A, B and C) constructed from the theory by Dr. H. E. White, of the University of California. These show the hydrogen atom in several of its various states, transitions between any two of which result in the emission of one of the colors in the hydrogen spectrum. It is this special distribution of the electron during the course of its rapid wandering about the nucleus which determines the diameter of the atom, for it is known that the outer boundary of this electron cloud is impervious to the approach of other atoms. So complete, in fact, is our knowledge of the atom that we might even calculate to what extent one atom would dent another if the two were dashed together with some known velocity. In short, we may think of the atom as a corpuscle having as definite properties as any ball which we can take in our hands and examine.

It is of interest to inquire about the rules which govern the motions of these atom balls through space. Just as it is necessary to know something about the motor vehicle laws to understand the procession of automobiles on the public highway, so our knowledge of the structure of the atom must be supplemented by a familiarity with its laws of motion if we are to understand the phenomena of nature in terms of the underlying atomic processes. What, if anything, can be said in general about the motions of these tiny corpuscles? Is there some rule, common to all atoms, by which we may know where they may be found in space at any predetermined instant and, if so, what initial information is necessary to supplement this rule in order that such a prediction can be made?

This is the problem which confronted Sir Isaac Newton in the case of the motions of the planets. The acceleration or the rate at which these bodies change their velocity, he discovered, is a quantity which depends upon the position of the body in space relative to other bodies, and it is independent of the velocity with which the body is already moving. As an illustration we may think of a shower of meteorites falling towards the earth with various velocities. If, at a distance one thousand miles above the earth's surface, one of these meteorites, already moving with a velocity of 30,000 feet per second, should increase its velocity during one second of its fall to 30,020 feet per second, Newton found that the general law of motion was such that another meteorite with a velocity of 20,000 feet per second at the same place would, in the same length of time be expected to increase its velocity to 20,020 feet per second. The change in velocity per second would be the same for all bodies at that place regardless of the velocity already possessed. This rule of motion lies at the base of a deterministic view of the world, for, by its use, one need only be familiar with the unchanging properties of space through which a body may travel in order to be able to calculate from the position and velocity of the body at some particular instant where it was at all past times and where it will be at all future times, and to compute the corresponding velocities. In other words, a body's complete history, both past and future, may be written if its present state is known. Since the question of determinism has always been a debatable point in philosophy, one now realizes from another aspect the importance of a knowledge of the laws of motion of the atom. It is, of course, to be realized that the exact condition of any large-sized object is completely determined by the positions and velocities of its constituent atoms and if these are completely determined by the positions and velocities at some previous time, one can scarcely avoid the deterministic view of the world.

But *is* it possible to predict the motion of an atom by means of Newton's law or by some other law so that once its position and velocity are known its position

and velocity throughout all time may be determined? If such is the case it should be possible in principle, even though too difficult in practice, to observe the positions and velocities of all the atoms in the world to-day and then to calculate where they were and how fast they were moving a million years ago or a million years hence. In fact, the entire history of the world, accurate to the most minute detail, would be contained in its present state, if some such rule holds true. But the answer which experiment gives to this question is, "No, there is no rule by means of which one can make such a prediction from any present knowledge of the atom."

The situation may be illustrated by an analogous state of affairs long known to exist in the case of the motions of the corpuscular rays of light. Although the failure to find such a rule in this case led scientists for nearly a century to give up the idea that light is of a corpuscular nature, now that its corpuscular properties have been firmly established, the situation may be described as though this fact were recognized from the beginning, as is the case with the atom.

Exactly how does the Newtonian rule fail to describe the motion of a light corpuscle? The trouble may be illustrated by thinking of a simple experiment. Let us imagine three points, A, B and C, all on the same straight line, and let us suppose we know that a light corpuscle has passed through the points A and B and has arrived at C. This corpuscle has served to explore the space along the line of its path so that Newton's law may now be applied to a second light corpuscle which passes through the points A and B. Since the first corpuscle was undeflected from the straight line, the properties of the space are such that between the points A, B and C, one light corpuscle has gained no sidewise component of velocity. Newton's rule states that the gaining of velocity is a property of space, the same for all similar corpuscles and hence it should follow, if his rule applies, that the second light corpuscle will also arrive undeviated at C. This experiment was first carried out in 1821 by Thomas Young. Fine apertures were placed at the points A and B and a screen contained the point C. If the Newtonian law were true, the spot of light formed at C should have remained sharply defined and have become narrower and narrower as the apertures at A and B were made smaller and smaller, for the law demands that all corpuscles describe identical paths to within the angular aperture of the two diaphragms A and B. The result found, however, was that similar corpuscles did not follow identical paths to within this angle and the beam at C was broadened beyond the aperture of the slits. In fact, after the slits were narrowed beyond a certain amount the beam became broader and broader. The Newtonian rule, therefore, did not apply to light corpuscles under these conditions of motion, and some other formulation of the law of motion of the light corpuscle was necessary. For this purpose the classical wave theory of light was developed.

Although the philosophical view of this theory has changed from time to time, the present aspect, based upon the experimental proof of the existence of the light corpuscle, is somewhat as follows. If a single light corpuscle emanates from a fine hole and passes through a system of apertures, prisms, lenses, mirrors and what not, and falls upon a screen, we can make no definite prediction as to just where it will hit. The most that we can predict are the relative numbers which will fall on the various parts of the screen in case a large number of such corpuscles emanates from the hole and this prediction is carried out, not by Newton's rule, but by the use of the following artifice. A wave disturbance is imagined to pass through the hole with a definite rate of propagation

at each point in space. The wave-length of this disturbance must be imagined to be inversely proportional to the momentum (mass times velocity) of the corpuscle, and its intensity in front of the hole must be proportional to the number of corpuscles emerging per second. We must next imagine this wave to be propagated through space according to the well-known laws of wave motion and to appear with calculable intensities over the entire area of the screen. Apparently, what we can say about the corpuscle then is that the relative numbers appearing at the various points on the screen are proportional to the intensities of the imaginary wave disturbance at these points, but, beyond this, no prediction can be made about the path followed by any particular corpuscle. It is as though we were to describe the motion of a ship in the following mysterious way. If the ship were scheduled to leave New York Harbor at some definite time and we should attempt to predict its appearance in some other harbor at a later time, we would have to realize that uncertainties existed which made an exact prediction impossible and all that could be done would be to state the relative chances of its appearance in each of the harbors of the world. This prediction would be carried out in the following artificial way. At the time the ship was scheduled to leave the harbor a wave would be started by exploding a charge of dynamite under the ship's keel and this wave would propagate itself across the ocean and produce disturbances in all the ports of the world at later times of intensities which could be calculated from a knowledge of the original disturbance and the characteristics of the shore, the latter coming in to take account of reflections and slower rates of propagation in shallow waters. The chance of finding the ship in any port at any time would then be proportional to the intensity of the wave disturbance there. If the ship were a light corpuscle, something like this, it seems, would be the best that we could do about predicting its movements.

It was stated above that the corpuscular character of light has been firmly established experimentally. In a sense this is true, but really all that we know of the light corpuscle is based upon the fact that an electron, when affected by light, behaves as though it had experienced a blow from a corpuscular entity of a definite energy and momentum. Besides this fact, we actually have no knowledge of such properties as the size, mass or internal structure of the light corpuscle. Could it be possible that the failure of Newton's law to apply to the motion of light is after all due to a misconception of its true nature and, though light does seem to be able to deal corpuscular blows, it is really of an entirely different character and is not to be thought of as a shower of corpuscles?

Thoughts such as these need not annoy us at this stage of our knowledge, for similar difficulties have appeared in applying Newton's law to other corpuscular entities. The electron, besides sharing the corpuscular behavior of light, also carries a corpuscular charge and the atom is an entity as corpuscular as a baseball, the only pertinent difference being that it is one hundred million-million-million-million times lighter, and yet these entities of more distinct corpuscular characters are just as illusive as the light corpuscle in not allowing us to know exactly where they may roam. The trouble is obviously not with the corpuscular concept but with the laws of motion of the corpuscles. In fact, the motions of all these corpuscles must also be described by a wave artifice.

This fact, first suggested in 1923 by de Broglie, has been confirmed experimentally by the now famous experiments of Davisson and Germer, in the case of the electron; and in the case of the atom, by the recent experiments of Estermann and Stern and those of the author.

A simple experiment for testing the applicability of Newton's law with two slits and a screen has already been described. This method, which was the first to reveal the wave character of the motions of the light corpuscle, could have been used also with the atom or the electron, but it has the practical drawback that it is exceedingly difficult to construct a slit fine enough to produce an appreciable broadening of a beam of either of these entities. It is a characteristic of the wave description of the motion of a corpuscle that a deviation from the Newtonian description, for example, a broadening of the beam, in the slit experiment, occurs only if the wave-length of the imaginary wave is comparable or longer than the dimensions of the slit. In the case of visible light this wave-length is about five ten-thousandths of a centimeter but in the case of a beam of atoms moving with the velocities which occur in a gas at ordinary temperatures the wave-length is another ten thousand times smaller and hence it is almost beyond the limits of the finest machine shop practice to construct a slit that is narrow enough to produce a broadening of as much as one degree beyond the angular aperture of the slits themselves.

As it often happens in experimental science, when man fails, nature lends a helping hand and in this case an almost ideal piece of equipment may be found in nature's stockroom. The surface of a crystal, being made up of an array of similar and regularly spaced atoms, in fact, constitutes an array of slits of just the width needed. When an atom beam falls upon a crystal surface the atoms of the crystal are good reflectors, whereas the interstices between the atoms are poor reflectors. The atoms themselves then are the slits. The fact that they reflect rather than transmit fortunately introduces no important differences into the argument. There is, however, one difference between the experiment of reflecting an atom beam from a whole array of tiny mirrors and that of reflecting the beam from just one mirror, the latter experiment being the exact equivalent of the slit experiment already described. The difference, however, is one which has long been known to the physicist, for just such arrays of tiny mirrors as those constituting the surface of a crystal have been constructed for many years on the ten thousand times larger scale for studying the waves of light.

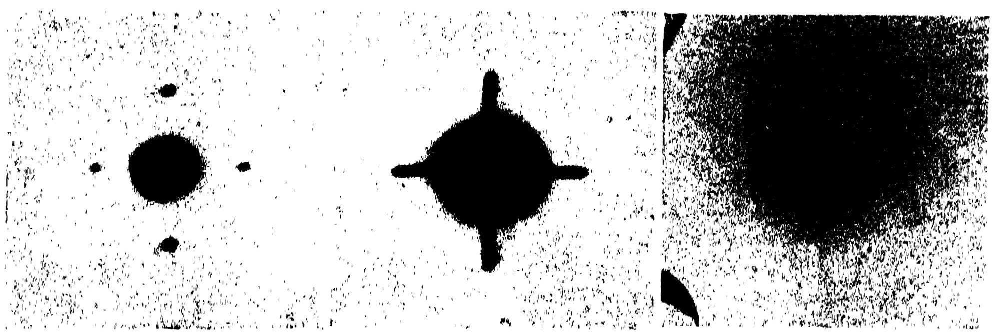
A discussion of the effect of the array on the broadening of a beam of waves would take us further into the theory of waves than is necessary for the purposes of this article, and it will suffice to state that the broadened bundle of rays from an array of mirrors includes as wide an angle as the rays from a single mirror of the size of just one of the mirrors in

FIG. 1. PHOTOGRAPHIC MODELS OF THE HYDROGEN ATOM IN THREE OF ITS MANY POSSIBLE STATES, CONSTRUCTED ACCORDING TO THE MODERN THEORY BY DR. H. E. WHITE.

the array. There is, however, the difference that the single mirror sends rays into all the possible directions included within this bundle, whereas the array of mirrors sends rays into only a few of these directions. The interesting and instructive fact about the array is that the directions which it selects out of all the possible ones are related in a very definite and simple way to the wave-length. For this reason, the crystal experiment allows us not only to prove that the motion of a beam of atoms must be described by a wave artifice, but it enables us to measure the exact wave-length of the waves. The results, as we shall see, happen to have rather far-reaching philosophical consequences.

Instead of going further into the description of what is to be expected if an atom beam behaves as a wave when reflected from a crystal, it is more convenient to call attention to the pattern shown in Fig. 2a, which is a photograph of what appears on a screen when a beam of light of some definite color is reflected from an artificially constructed array of mirrors, each mirror being five ten-thousandths of a centimeter on a side. If some other color or wave-length were reflected from the same array, the number of these beams would be the same, but their positions would shift along the lines drawn to the center of the pattern. The pattern produced by white light, that is to say, light of a continuous range of wave-lengths, therefore, consists of a continuous series of such spots overlapping along these radial lines. Such a pattern is shown in Fig. 2b.

The motion of the light corpuscle, we know, requires for its description the wave artifice if these patterns are to be explained. The proof that the motion of the atom follows the same type of law now rests upon the similarity between the pattern of Fig. 2b and that of Fig. 2c, the latter being the pattern which appears on a screen which receives atoms which have been reflected from a crystal surface. The correspondence between the two patterns is complete and it shows that Newton's law is no more adequate for the description of these newly discovered motions of the atomic corpuscle than for the old familiar vagarious paths of light.



(a) (b) (c)

FIG. 2. (a) THE PATTERN FORMED BY LIGHT OF ONE COLOR WHEN REFLECTED FROM AN ARRAY OF MINUTE MIRRORS. (b) THE PATTERN FORMED BY LIGHT OF MANY COLORS WHEN REFLECTED FROM THE SAME ARRAY OF MIRRORS. (c) THE PATTERN FORMED BY HYDROGEN ATOMS OF MANY VELOCITIES REFLECTED FROM THE ARRAY OF MIRRORS COMPOSED OF THE INDIVIDUAL ATOMS ON THE FACE OF A CRYSTAL OF LITHIUM FLUORIDE.

Why is it that the atom's motion defies exact description according to the Newtonian law when larger corpuscles such as a marble appear to follow this law exactly? The answer can be learned from the experiment, for by a study of the distribution of intensity along the

arms of the pattern in Fig. 2c, a relation is found between the wave-length and the momentum of the atom. This, in fact, turns out to be just that predicted by deBroglie, *i.e.,*

$$\text{Wave length} = h \div (\text{momentum})$$

where h is a constant having the value 6×10^{-27} in the centimeter- gram- second system of units.

If this same relation is applied to the motion of a marble, its wave-length turns out to be so small compared with the width of any slit through which the marble would pass that it would be impossible to detect any uncertainty in its direction to within the minute angle subtended by the width of a hair at the distance of the most remote spiral nebulum.

Perhaps the most remarkable aspect of the newly discovered laws of atomic and electronic motions is the fact that it is now possible to include all motion under one law; the same for light corpuscles, electrons, atoms or large-sized objects. Everything is guided by a wave whose wave-length is related to the momentum of the corpuscle by the mysterious constant h, the Newtonian law now appearing as an approximation, though a very good one in the case of the objects of our ordinary experience, to the more general and fundamental wave law. A unification of this kind is, of course, very satisfying, for it leads us to believe that our knowledge of all types of motion is now complete.

Whenever some new law of nature is discovered it is a most natural question to ask, "To what use for the benefit of humanity can the new knowledge be put?" In fact, man is perhaps even more interested in trying to put natural forces to some useful purpose than he is in trying to understand them. Will it be of any use to humanity to know the laws of motion of the atom? To answer this question one need only recall the passive state in which the science of engineering lay up to the time Newton learned to understand the laws of motion of large-sized objects and then to note the great difference this knowledge made in man's ability to help himself with all kinds of machinery. May it not be possible that the 250 years following the discovery of the fundamental laws of atomic motions will witness as great a development in man's control over the atom as the last 250 years since Newton have witnessed in the development of man's control over the machine. In fact, the new knowledge is already laying a theoretical foundation to the science of chemistry which can scarcely avoid leading to new and beneficial developments. The formation of compounds or alloys having any desired physical properties, predictable in advance, is just one of the results to which this science may lead. Since all material substance is made up of atoms, a thorough understanding of the atom should lead to an understanding of all forms of matter.

THE EXPOSITION OF SCIENCE[1]

By Professor HENRY CREW

PROFESSOR OF PHYSICS, NORTHWESTERN UNIVERSITY AND CHIEF OF THE DIVISION OF BASIC SCIENCES AT THE CENTURY OF PROGRESS EXPOSITION

An eminent man of letters, an Enlishman, has recently likened modern science to a rich uncle who has brought to the nursery more toys than the children know what to do with. Mr. Wells might have gone further and added that, as the panorama of life becomes more complex and more mysterious in this nursery occupied by us "children of a larger growth," the need for analysis and brief summary becomes more urgent. Were I to say that such an epitome of what we have learned may be obtained by conversation, by reading, by expository lectures, by scientific exhibitions and by experiment, you might infer that the exposition of science appears to me an easy problem; but I want to assure you that quite the reverse is true. If I were to confess to you that I have been engaged continuously for forty-five years in the exposition of science, you might think that I know something about the subject; but I want to assure you that quite the reverse is true. The exposition of science is a subject which appals me by its complexity, and I am still wondering how I ever came to promise Dr. Cattell that I would speak here upon this topic; for the subject is one upon which I have had no leisure to read, and small liberty to experiment. My only apology must be, I fear, that I have enjoyed a fairly long period of observation. Accordingly, the most I can do is to share with you some of my observations.

First, and incidentally, I have observed that differences of judgment in men result most frequently, not from differences in method of reasoning but from differences in definitions and from difference in premises assumed. Let us, therefore, at the outset, agree if possible, upon the definitions of the two words, "exposition" and "science." The first of these is employed very nearly in its literal sense which is merely the setting forth, the placing of an object or subject out in front where it may be seen and grasped by all. We may safely assume universal agreement as to the meaning of "exposition," in spite of the fact that the New English Dictionary gives eleven different definitions.

When, however, it comes to "science," the matter is quite otherwise. Here the great Oxford compendium gives us more than a dozen different senses in which the word is employed. Usage is, indeed, so diverse that one feels almost like saying that each man must make his own definition before he begins to speak. On the other hand, there is, I imagine, in this particular group, that is to say in this Association, more unanimity in the use of the word "science" than in any other group of equal size in America.

To put the matter in another way, what is the thing in whose advancement this Association is particularly interested? Is there, indeed, any one thing which we have in mind when we foregather, as here in Syracuse, and speak of science? This latter question must, I fear, be answered in the negative. At least I feel pretty certain that no single definition can be framed that will satisfy all my friends. To define anything is to

[1] An evening lecture before the American Association for the Advancement of Science at its Syracuse meeting, June 24, 1932.

draw a boundary which shall include all that thing and exclude all which is not that thing. In attempting to describe the best usage, I would be inclined to say that the field of science includes all the phenomena which men have observed and correlated; but of course, with the understanding that the observer is a normal individual and that the phenomena are such as can be observed by other normal individuals.

If, however, the range of science be limited to phenomena, the question at once arises as to what is to be done with human purposes, as these express themselves in, say, literature, history and politics? Where is one to classify the assumptions of mathematics and the art of drawing correct conclusions from these assumptions? So far from placing this discipline outside the pale of science, there is a general feeling that mathematics, although mainly deductive, is an ideal science; what Münsterberg called a normative science. Mathematics and logic describe, in a certain sense, our experience as to how the normal mind works in arriving at correct judgments.

The best formulation of this restricted definition of science that I have seen is the one given by Professor Herbert Dingle, the well-known English astronomer, in a charming little volume, which appeared last year, called "Science and Human Experience," where science is defined as "the recording, augmentation and rational correlation of those elements of our experience which are actually or potentially common to all normal people."

Here is a definition which is wide enough to include mathematics at one end of the series, with psychology and anthropology at the other end; and narrow enough to exclude literature, history, politics, religion and all matters of taste where experience is no longer common to you and to me. Dingle's formulation is restrictive: it excludes the whole group of what Münsterberg calls the "Historical Sciences;" But it describes very perfectly, I feel, just what our Association is attempting to advance. It includes what we all call the natural sciences and excludes what Dr. Cattell calls the unnatural "sciences," namely, politics, economics and sociology. Furthermore, this definition implies just what is understood by scientific method. This is the science which has aided industry, the science which has given us increased leisure even to the point where a reduction of leisure would bring an increase of happiness to several millions of our fellow citizens.

The Systematic Exposition of Science

Using science in exactly the sense in which Professor Dingle has employed it, let us compare for a moment some of the fundamental modes of its exposition. One who has noted the tender age at which an infant, having dropped a toy, will learn, not to direct his gaze all around the room, but to look toward the floor; or one who has witnessed the surprise of a little child when a piece of ice melts and disappears in the warm grasp of his small hand; or one who has observed the promptness with which this same child learns to steer clear of a hot stove, is not likely to under-estimate the efficiency of the experimental method of acquiring knowledge. The three examples which I have just cited might perhaps be called independent investigation, rather than exposition. When, however, this same child becomes old enough to ask his father questions, or when he comes to his mother for explanation of how this, that and the other thing works, and when the intelligent parent answers the child's inquiry by a practical demonstration before his eyes, one has the exposition of science at its very best; native curiosity satisfied by

Courtesy of the Chicago Aerial Survey Co.

GENERAL VIEW OF THE EXPOSITION GROUNDS,

JULY 1, 1932. ELECTRICAL BUILDINGS IN THE CENTER OF THE FOREGROUND.

immediate observation, experiment and conversation; a word of suggestion rather than complete analysis is often all that the parent has time to give; and this slight stimulation is, perhaps, the most perfect form of instruction.

In high school and college, all but a few first-class minds are likely to become slaves to the text-book, more interested in examinations than in the subject; the edge of native curiosity is likely to be dulled; mathematical formulae are likely to be substituted for good common sense. The experimental lecture helps to some extent, especially if there is plenty of give-and-take across the demonstration table. The longer one's experience with America's experiment of educating all grades of minds in the same class, the more keenly he realizes the dangers of a college course and the more clearly he grasps the point of the old proverb that "Truth can be expressed only in the form of dialogue."

Coming to graduate work, that is to graduate work properly so-called, one meets again the contact of mind with mind, the indispensable personal element, and the individual private study which make the exposition of science to eager, gifted, advanced students tremendously effective and productive. In all that I have said about the dangers connected with the exposition of science as one meets it in college, there is not the slightest derogation of the student himself. For, of all the various groups that make up the modern university, the young people who fill the freshman seats are doubtless the least spoiled, the most sincere and the most straightforward. No man whose imagination has not atrophied can ever stand before a college class without thinking that these are the men who twenty years hence will be running the world, with the chances all in favor of their running it a little better than those at present in charge.

The Popular Exposition of Science

Leaving now the systematic presentation of science, which begins in the home, carries on through the schools, and is eagerly sought throughout life by men of science, we pass to the problem of offering science to the public, a problem which assumes new importance in view of the fact that the very existence of the human race appears to depend upon our ability to adapt ourselves to the innovations of science and to the new environment which science has created. Indeed, it is not unlikely that, before the end of this century, science will play a rôle quite as dominating as that of the church during the thirteenth century.

That the popular exposition of science is a duty which workers in science owe to the public is manifest from the fact that the public is now the principal patron of science. There is no servility connected with such an exposition. It is no longer necessary for a distinguished scholar, such as Daniel Bernoulli, to dedicate his work to "your highness, most serene and most gracious lord" and then sign himself as he does in his great treatise on hydrodynamics, "Humillimus et obsequiosissimus servus, Daniel Bernoulli." The individuals who patronize science to-day generally do it through public institutions, such as the Rockefeller Foundation, the Carnegie Institution or an important university such as that in which we are now assembled.

Newspapers

One would naturally think that the best way to transmit the rather technical results of science to the public would be first to translate these results into clear and simple English and then leave the rest to the daily press. If, however, any one thinks that a newspaper would gladly use such material to fill the space that is left over, after the advertise-

Courtesy of the Chicago Aerial Survey Co.

THE HALL OF SCIENCE,
JUNE, 1932. ARCHITECT, MR. PAUL CRET.

ments have been taken care of, he is doomed to disappointment. "Clear and simple English" is not sufficient. Newspapers differ, of course; and there are exceptions to all rules; but in general an article on science must be "jazzed up" in order to be acceptable. The style must be interesting; the results striking. This means that the evidence upon which a result depends is frequently omitted; there is little distinction drawn between inference and experimental fact; figures are often used to give an external appearance of precision, while in fact the first essentials of accuracy are wanting. I fear I am almost alone in thinking that the same American public, which so enjoys the solution of crossword puzzles, would also enjoy unravelling the argument for many an important laboratory result in biology or physics, if only the sequence were presented in such a way that each statement hinges upon those which precede it. There is so much new material constantly appearing and so many old results unknown to the public that there never can be any dearth of news for any paper which desires to print a column of science in each issue.

The crying need in the exposition of science by the daily press is first of all a higher regard for the exact truth and a recognition of the fact that accuracy is the first step toward morality. The second need is that men of science should cultivate a more artistic and more logical presentation of the truth.

International Expositions

Coming now to international expositions, which is the restricted topic upon which I was invited to speak, one finds here a method of presenting science which has new possibilities, because it is purely voluntary; it requires no examinations, not even reading; it touches only the high points; it stimulates by suggestion so to speak; it appeals to the eye; it may weary the body; it never wearies the mind. These fairs offer an opportunity to celebrate the great idealists, who after all are the most practical men in the world. A well-arranged exposition offers to each visitor almost the ideal conditions of his early boyhood when he inquired of his father why the little hydrogen-filled balloon rose to the ceiling of the room instead of falling to the floor. It is generally conceded, I believe, that the earliest exposition on record is the one staged at Shushan by the Persian King, Ahasuerus, and described in the first chapter of the book of Esther. The Kingdom of Ahasuerus is there said to have included 127 provinces and to have extended from India to Ethiopia. The period of the exposition was 180 days and may well be called a world's fair.

It would be interesting, if time permitted, to imagine just what would have been shown at a world fair, say in Egypt 1500 B. C., or at Athens in the fifth century B. C., or at Rome about the beginning of the Christian era. One would doubtless be surprised at the new devices presented in the way of tools, boats, looms, sleight-of-hand performances, works of art, musical instruments, implements of war, pharmaceuticals; but one would hardly expect much save geometry in the way of that systematized knowledge which we call science.

Socrates is said to have enjoyed strolling down the streets of Athens, looking in at the shop doors, and seeing how many things he could do without; and we may be sure that the ancients were not a whit behind us in native curiosity and the spirit of inquiry.

Passing on to the fairs of medieval times, all these were essentially commercial. Many such glorified markets were held between the thirteenth and

Courtesy of the Chicago Aerial Survey Co.

THE ELECTRICAL BUILDINGS

AS SEEN LOOKING EAST FROM THE HALL OF SCIENCE. ARCHITECT, MR. RAYMOND HOOD.

nineteenth centuries; but it is not until 1756 that we meet a modern exposition, the one that was staged by the Society of Arts at London in 1756.

The prizes won at competitive shows of this kind enhanced the reputation and the business of the winner; but science was still in the hands of the individual and of a few academies. Products, not processes and much less theory, were the chief attractions. The great show at the Crystal Palace in London in 1851 was the first one of international character. Its main building in Hyde Park covered 20 acres. The architect, Sir Joseph Paxton, had been trained as a landscape gardener and the design was that of a glorified greenhouse. The attendance was about six million. Similar exhibitions rapidly followed in Paris, Munich, London, Rome, New York and Dublin.

Centennial at Philadelphia

The Philadelphia Centennial in 1876 marks the beginning of a new era; transportation facilities in the United States were just reaching the stage which might be called ample. The Pullman sleeper, the railway post office and the dining car were all in their early stages. The great Corliss engine which dominated Machinery Hall typified the age of the automatic machine just then beginning. Maxwell's monumental treatise, "Electricity and Magnetism," had been off the Oxford Press for three years, but few regarded this great work, which unified the entire subject of electricity from the amber phenomenon of Thales to the modern radio set, as anything but a *tour de force* of mathematics—a bit of highbrow stuff.

It is true that the Belgian engineer, Gramme, had on display at Philadelphia two or three small dynamos of his design. Professor Anthony and the late Professor Moler of Cornell had, in 1875, constructed a generator which was also shown there. Graham Bell and Elisha Gray each had exhibits which were listed in the official catalog under the head of "the electromagnetic telegraph"; but the average visitor then regarded the telephone (if, indeed, he had ever heard of it at all) as an electrical toy and nothing more. Sir William Thomson, returning to England, reported it, however, as the outstanding exhibit of the Centennial; a few months later Maxwell devoted to it his famous Rede Lecture; a few years later and "Their voice is gone out through all the earth and their words to the end of the world." But anything in the way of the fundamental and basic sciences at the Centennial was conspicuous by its absence. In consequence of the various experiments of Volta, Davy, Oersted, Faraday, and by the splendid mathematical descriptions of Neumann, Kirchhoff, Kelvin and Maxwell, the ground had been prepared for a rapid advance in electrical industry.

Columbian Exposition

The result was seen in the Columbian Exposition in 1893, when next to beautiful architecture, electric lighting, electric power, electric welding played a leading rôle. An electrical carriage made occasional trips about the grounds: a Daimler petroleum motor did the same. Navigation of the air had not reached even the experimental stage. The Columbian Exposition housed some excellent things in pure science such as Lippmann's photographs in color, the gigantic Yerkes telescope just then nearly completed; but these were mostly static and represented apparatus and results rather than phenomena and processes. Industrial electricity commanded the field. Nevertheless, an international electrical congress was held; it was by this congress that the practical unit of

inductance, the henry, was defined and named. Another international convention was devoted to mathematics. These assemblies were honored by the presence of such men as Helmholtz, Silvanus P. Thompson, Rowland, Klein, Study, and others.

Paris, 1900

Seven years later came the Paris Exposition, where science was exposed, so to speak, in several remarkably fine international congresses, covering not only the physical but also the social sciences. Most of the displays, were, however, again of apparatus and results rather than of phenomena and methods. The steamer *Turbinia* was at anchor in the Seine, while, in one of the halls, a beautiful turbine engine of Sir Charles Parsons was running so quietly that an English penny remained standing on edge on the top of the cylinder. But the outstanding features of the show were military and commercial. On the front of the German steamship building, in large gilded letters, one read the significant phrase "Unsere Zukunft liegt auf das Wasser." Equally impressive were the implements of war shown by the great factories at Creusot.

The newly discovered element, radium, was then very young; and no one present can ever forget the youthful Madame Curie presiding over certain sessions of the International Congress of Physics; unforgettable is also the experimental lecture in which her distinguished husband set forth, by actual demonstration, before an amazed audience, the striking and essential properties of the new element; but these features which I am mentioning belong rather to an international congress than to the exposition; they were favors to delegates; not privileges belonging to every visitor. In the same category belongs the already classical paper given by H. Poincaré upon "The Relations between Experimental and Mathematical Physics." Some beautiful electrical phenomena were shown by Prince Roland Bonaparte in his private laboratory; but these again were reserved for invited guests.

St. Louis, 1904

Four years later came the Louisiana Purchase Exposition at St. Louis which, in spite of being a commercial competitive institution, assembled what is perhaps the most noteworthy gathering of scholars the world has ever seen in one place at one time. Here was an attempt to present not only the best that had been said and done, but also the most important pending problems in the 127 great fields of learning into which all knowledge had been profoundly and cleverly analyzed by the committee in charge of the congress. The entire plan was the product of the mind and imagination of three very wise men, Simon Newcomb, Albion W. Small and Hugo Münsterberg, none of whom, unfortunately, are any longer with us. Here again on the program was H. Poincaré, speaking upon mathematical physics; Oswald, the distinguished German chemist, spoke for philosophy, a subject to which all his later years were devoted; Woodrow Wilson discussed a wide historical topic. The addresses, which fill eight large octavo volumes, are all comprehensive without being superficial; in this respect they are markedly different from any eight volumes of papers read before specialist societies.

Here again at St. Louis the exhibits in science were mainly along the line of electrical engineering, transportation and other applied sciences. Pure science nowhere presented a united front; and the same might be said of various other expositions of recent times, such as those of Buffalo, Jamestown, Seattle, Antwerp and Stockholm, all of which I have

myself visited with especial attention to science, pure and applied.

CHICAGO, 1933

The Century of Progress Exposition at Chicago was conceived, by a small group of clear minds, in the summer of 1928. From the very start they abandoned the idea of competitive exhibits and juries of award; instead of this they took as their principal theme the dependence of industry and commerce upon pure science. Their aim was not merely to entertain their visitors, but also to acknowledge and demonstrate our indebtedness to the quiet investigators of the century following the incorporation of the city of Chicago in 1833. Confidence in this plan was strengthened by the approval of men such as Michael Pupin and George E. Hale, who are at once productive scholars and men of affairs.

It was early seen that the demonstration of a theme such as this requires an exhibition of the fundamental sciences in such completeness and in such a shape as to be both understandable, adequate and attractive to the public. The trustees also recognized that in addition to science and industry no fair of this kind could hope to succeed, in its high purpose, without some lighter forms of entertainment which bring sunshine, laughter, rest, recreation and help to ameliorate the more drab circumstances of life. Music and art also are essential. Nor could any Anglo-Saxon Exposition hope to succeed unless healthful sports were fairly represented.

An inspiring theme—the service of science to society—having once been adopted, the next step was its execution. At this point Mr. Rufus Dawes, the president of the exposition, was courageous enough to ask Dr. George Burgess to go before the National Research Council and invite this body to appoint a committee for the express purpose of suggesting just what features and facts of science should be disclosed to the public in order to give an adequate conception of the method and achievements of modern science, pure and applied.

As most of you know, Dr. Burgess was, in his turn, wise enough and courageous enough to ask Dr. Frank B. Jewett to accept the chairmanship of a group of leading American scholars who, acting as an advisory committee, have given the exposition, in the most unselfish manner, a report of high order and rare completeness. The generosity of this committee will never, never be forgotten. It is upon the execution of this report that the Division of the Basic Sciences of the exposition is now engaged—and has been engaged for more than a year past.

To an audience of this intelligence, it is needless to say that the plans of large undertakings have generally to be modified during execution and that, in times of depression, these changes may be largely in the form of contractions.

For purposes of operation, medicine and geology are both grouped with the basic sciences, although each of them is largely an application of chemistry, physics and biology. Accordingly, the Division of the Basic Sciences includes the following seven sections—Mathematics, Astronomy, Physics, Chemistry, Biology, Geology and Medicine. The endeavor of these sections is to present a united front of the physical and natural sciences to the American public. Psychology has been associated with anthropology, as in the organization of the National Research Council, and will probably be housed in separate quarters assigned to anthropology.

The aim of our staff is to interpret to the American people the spirit of the National Research Council Committee as inspired by Dr. Burgess and Dr. Jewett.

In attempting this we are attempting to demonstrate the theme of the fair and to make plain what is meant by scientific method, which after all is the one outstanding achievement of the last three centuries. To show phenomena rather than apparatus is not easy; but that is what we are attempting; to show the processes of life rather than museum specimens is still more difficult but that is what we are attempting. An important part of our task is to make the atmosphere of science generally comprehended. For if science fails to recommend itself and its method to the explanation and the cure—the permanent cure—of such depressions as we are now in, it must for the present confess defeat. My own belief is that men of the same type as those who led the last century of progress will lead us through the coming century; so great is my faith in the value of good method.

Incidentally, it may be mentioned that the Chicago Exposition is cooperating with Messrs. Williams and Wilkins in the publication of a group of some twenty small volumes to be known as the "Century of Progress Series." Each of these books—five of which are already off the press—is written by a well known scholar and deals with an important section of modern science; the series as a whole will, it is hoped, represent, in a clear and simple manner, the front line of recent research.

In conclusion, may I remind you that the council of this association has cooperated with the trustees of the exposition in bringing to our next summer's meeting in Chicago a goodly number of foreign men of science? When, to the list of scholars included in our own membership, one adds the acceptances already received from overseas guests, he sees that the prospects for the exposition of science in 1933 are reasonably bright.

HERBS, HERBALS, HERBALISTS

Some Sketches from the History of Medical Botany in the Old World

By Dr. HELEN BANCROFT
THE SCHOOL OF RURAL ECONOMY, UNIVERSITY OF OXFORD

In the very early days, many thousands of years ago, when man first began to live on this earth of ours, his need for food soon led him to distinguish those plants, or parts of plants, which were good to eat from those which were harmful; and, no doubt, at a very early stage, he also discovered that various plants had valuable tonic or curative properties, when he chewed them, or applied the bruised leaves and stems to his wounds.

The old British herbalist, John Parkinson, who lived between 1567 and 1650, and who was "Apothecary to James the First" and "Botanist to Charles the First," published a "Garden Book" in which he makes this statement: "God, the Creator of Heaven and Earth, at the beginning, when He created Adam, inspired him with the knowledge of all natural things (which successively descended to Noah afterwards, and to his posterity): for as he was able to give names to all the living Creatures according to their severall natures: so no doubt but hee had also the knowledge, both what Herbs and Fruits were fit, eyther for Meate or Medicine, for Use or for Delight."

While we can hardly agree with Parkinson that the first man knew all about herbal remedies from the beginning, there is no doubt that necessity would soon bring about the gradual acquiring of knowledge. Such knowledge would, of course, at first be handed on from generation to generation by word of mouth; and to this day, in India and Ceylon, amongst people of very old civilizations, as well as amongst the Zulus and other, more primitive, African tribes, though many wonderful plant remedies are known to the natives, they are guarded very jealously, and are still handed on from father to son by word of mouth only.

Compared with the whole history of man—covering, probably, a period of some 300,000 years—and of his knowledge of plant medicines, actual herbal writings, or "herb-books" are few, and of fairly recent date, though, as we shall see, some were produced by the Greeks, even before the time of Christ.

Amongst the accounts which are given of "healing by herbs," some are true, some are quite likely stories, some are very doubtful, and some are obviously pure imagination. In course of time, a great deal of superstition came to be attached to the use of herbal remedies, and so they fell into considerable disrepute amongst the more scientifically minded people. Scientists are now, however, beginning to investigate the chemical properties of herbs, and to understand why they may be valuable as medicines in certain cases; with the result that, in the last few years, herbal remedies have again come to be more widely used.

There is an old Jewish tradition, according to which herbal medicines were in use and were even committed to writing, in the time of King Solomon, about the tenth century before Christ. One of the thirty-nine books of King Solomon, it is said, concerned medicines, which were supposed to be largely herbal; for that the wise king knew much about plants is indicated in the first Book of Kings, in chapter four: "And he spake of the cedar tree which is in Lebanon, even unto the hyssop that springeth out of the wall." But if King

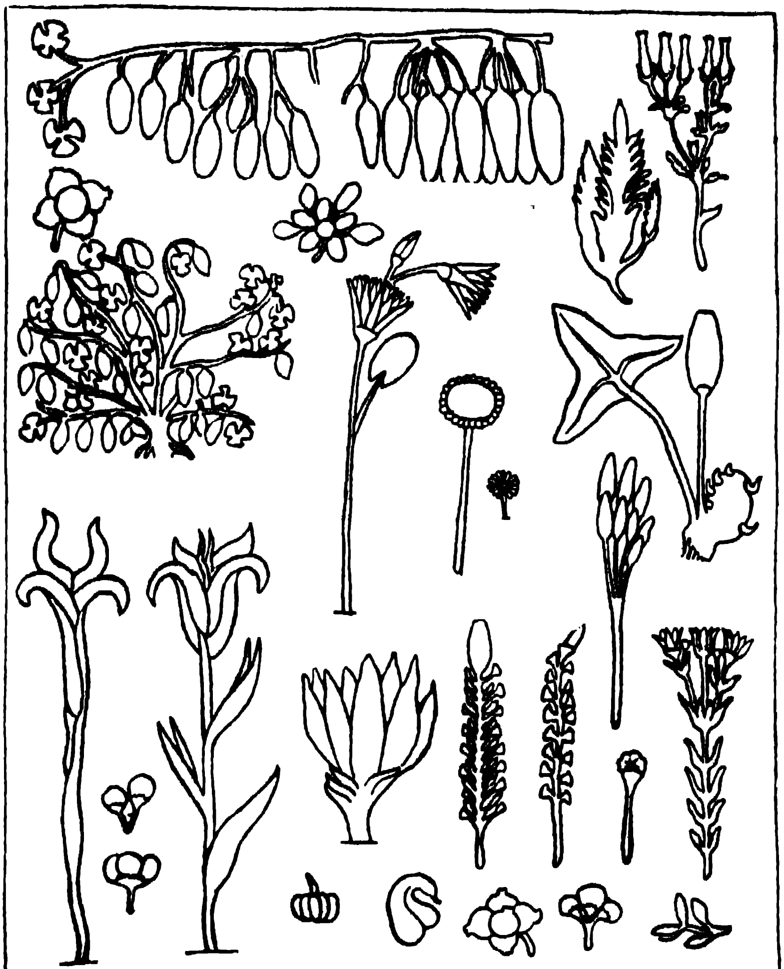


FIG. 1. PLANT REPRESENTATIONS FROM THE WALLS OF THE TEMPLE AT KARNAK

(REPRODUCED FROM SIR CHARLES SINGER'S "FROM MAGIC TO SCIENCE," BY THE COURTESY OF MESSRS. ERNEST BENN, LONDON, AND OF MESSRS. HORACE LIVERIGHT, NEW YORK.)

Solomon really did write a "herbal," no trace of it remains; and the Jewish tradition accounts for its loss by supposing that it was destroyed or hidden by King Hezekiah, because he thought that the people were placing too much reliance upon the use of the remedies it recommended. This is an interesting tradition, because one of the earliest definite references in literature to the use of a plant remedy is to the case of King Hezekiah himself, who, in about the year 713 B. C., was cured of a boil by placing a "lump of figs" upon it, at the bidding of the Prophet Isaiah.

But even before King Solomon reigned in Judea, there ruled in ancient Egypt a king, Thothmes the Third; and, in about 1500 B. C., this king sent an expedition to Syria, which brought back with it a number of new and strange plants. Representations of the plants were sculptured on the walls of the temple at Karnak, in Egypt, where they may be

seen to this day. The figures, which include recognizable irises and a heather, a seedling arum and a lotus flower (Fig. 1), are accompanied by an inscription, to the effect that the king caused them to be thus represented so that the knowledge of them might remain "for ever and ever." Sir Charles Singer, who is the English authority on the early herbals, calls these sculptures and their inscription a "herbal in stone"; they form the earliest *collection* of plant drawings of which we have any knowledge.

It was amongst the Greeks, however, that the study and use of plants in medical science became an established tradition, which has been handed down through the centuries. It is evident that the ancient Greeks were familiar with the use of herbal medicines at an early date; a well-known story from the Greek mythologies tells how Iapis, a favorite pupil of Apollo, was offered a choice of great skill in the foretelling of events, or in music or archery. Instead of any of these, however, he asked for a knowledge of herbs to cure disease. Armed with this knowledge, and with the help of Venus, he saved the life of Aeneas, when he was wounded by an arrow in battle. The old story says that Iapis used a purple-flowered plant called "dittany," which grew on Mount Ida in Crete (or Candia); Fig. 2 is a reproduction of a drawing of dittany from the 1636 edition of Gerard's "Herbal." Gerard describes the plant as being "hot and dry of Nature," and he adds, "it is reported likewise that the wilde Goats or Deere in Candy when they be wounded with arrows, do shake them out by eating of this plant, and heale their wounds." Dittany, it should be noted, is a relative of the marjoram which is grown in gardens as a flavoring herb, and to provide honey for bees; while herbalists to this day sometimes use this common marjoram externally for the healing of certain wounds and for easing stiff, "rheumatic-y" joints.

Returning to the ancient Greeks, we find the poet Homer, who lived during the tenth or ninth century before Christ, telling of Aesculapius, the god of healing. Aesculapius was the son of Apollo, the sun-god, and Coronis, the dawn-goddess, and he was carefully instructed by his father in the art of healing; the sun was regarded naturally, and rightly, as the restorer of life, and it was therefore natural that the sun-god's son should be endowed with curative powers. We are told that one chief source of Aesculapius' knowledge of healing was observation of the remedies resorted to by suffering animals—"what leaf or

FIG. 2. THE CRETAN HERB "DITTANY"
(REPRODUCED FROM A 1636 EDITION OF GERARD'S "HERBAL.")

berry the lizard or dormouse lay upon its wounded fellow"—and for the purpose of such observation, Aesculapius led the life of a pilgrim and wanderer in wild places for long years.

In course of time, temples were dedicated to Aesculapius, and the priests of the temples were called Aesculapiads—priest-physicians, who devoted their lives to the healing and care of sick people. Temples of Aesculapius survived in Greece and also in Italy for many years after the beginning of the Christian era. In his book, "Marius the Epicurean," Walter Pater describes such a temple near Pisa, even towards the end of the second century; at this temple, Marius saw the great physician Galen, to whom reference will be made later.

There was, then, in ancient Greece, a considerable traffic in medicinal plants, centered about these temples of Aesculapius. In course of time, however, the root-diggers and drug-sellers who made a regular business of collecting, preparing and selling these plants came to be regarded with some suspicion, because, apparently, they tried to keep their trade select by inventing superstitious stories which made it appear that herb-gathering was a very dangerous occupation. It was said, for instance, that peony fruits should be collected only at night, for if they were gathered in the daytime, and a woodpecker happened to witness the act, the eyes of the collector would be in danger. It was also said that an offering of a honey-cake must be made when *Iris fœtidissima* (the gladdon, or purple iris, sometimes found in English woods and thickets, as well as on the continent of Europe) was rooted up; and that if an eagle came near when hellebore was being gathered, the collector would die within the year. It is not surprising that people came to regard the herbalists, even in those early times, as rather ridiculous, and to feel a little suspicious of Aesculapius himself. This suspicion is expressed by the writer Lucian (about A. D. 160) in his "Dialogues of the Gods," where he makes Hercules address Aesculapius as a "wandering quack."

The ancient Greeks, therefore, believed that the gods were the first herbalists and physicians and that the art of healing was taught to man by them. The *real* founders of Greek medicine and the compilers of the Greek herbal-lore, however, were not the priests of Aesculapius, but ordinary people who wandered from place to place and earned their living by healing sick folk wherever they found them; one of the recognized and even famous herbalists of these early days was a woman named Agamēde.

The first Greek physician to work along lines more scientific and less bound up with magic and superstition than the methods of the herbalists was Hippocrates, who lived from 460 to 377 B. C. He used plants very largely as medicines—between three and four hundred are mentioned in what are known as the "Hippocratic writings"—though there is no evidence that he ever wrote an actual herbal; he probably drew upon lists of plants originally compiled by the Egyptians, for Hippocrates and other Greek physicians derived a great deal of their medical learning from Egyptian priests.

The first Greek herbal of which we have any knowledge was written about 350 B. C., by a brilliant physician called Diokles, who lived in Athens. His herbal, we are told, consisted of a description of certain plants, an account of where each might be found, and a list of its medical uses; unfortunately, this work has been lost, as well as most of the other writings of Diokles.

The next herbal of which we know is attributed to Theophrastus, a Greek philosopher who lived from about 372 to 287 B. C. Theophrastus wrote a great deal about plants, and was, as a matter of fact, the first really scientific botanist; the ninth book of his "Enquiry into

Plants" is the oldest Greek herbal which has actually come down to us. In it are described about 450 plants, knowledge of which he obtained, either at first hand on his travels, or, in the case of foreign plants, from caravan merchants. There is also a good deal of information in this herbal about the folk-lore of plants. Reference has already been made to some of the superstitious stories which the herb-gatherers invented to discourage people from entering into competition with them in their trade; the writer of this oldest-existing Greek herbal ridiculed many of these superstitions—that, for instance, which demanded the collecting of peony fruits at night only. He seemed, however, to think other superstitions quite reasonable, for he agreed that wild rose fruits and hellebore *should* be gathered "standing to windward."

After the "Theophrastan herbal," several herbal works are known to have been written in the third and second centuries B. C., but they have been partially or entirely lost; in the first century, B. C., however, a very important herbal was produced, namely that of Krateuas, physician to King Mithridates of Pontus. Krateuas not only collected herbs, but he wrote a book on their nature and uses; and later (about 75 B. C), he produced a second herbal, in which plants were not described in words, but were shown in pictures, and then discussed as to their medical uses. This illustrated herbal of Krateuas was the first of its kind, for the earlier books were without pictures of the plants described; after Krateuas, however, herbals were typically illustrated, so that Krateuas had a very far-reaching influence on the subsequent form and style of the herbal; Sir Charles Singer, in fact, calls him the "father of plant illustration."

The original drawings of Krateuas are, unfortunately, lost; but copies of them are known from a very beautiful herbal —the "Juliana Anicia" Codex—which which was written about A. D. 512 for a wedding gift to the daughter of an emperor of that time. This herbal may still be seen in what used to be the Royal Library at Vienna. One of its flower-pictures is reproduced in Fig. 3; it is evident that Krateuas was an artist of considerable merit. The plant is *Asarum europæum*,[1] the "asarabacca," which, since it was grown by monks for medicinal purposes, may occasionally be found in English woods as an "escape" from cultivation, though it is very rare; Krateuas recommended the plant for "chronic sciatica and dropsy," and also noted that it might be used in "perfumes and antidotes."

King Mithridates of Pontus, the master of Krateuas, who reigned from 111 to 64 B. C., was also an herbalist; but he was a much less reputable one than his servant, for he specialized in a knowledge of poisonous plants and used his knowledge to rid himself of people who were opposed to him. He greatly feared that

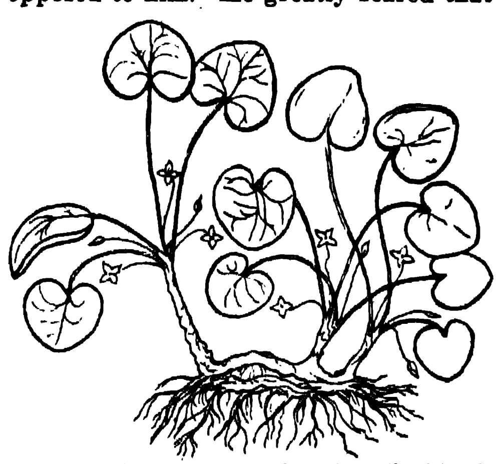


FIG. 3. *ASARUM EUROPÆUM*, FROM A SIXTH CENTURY COPY OF A DRAWING BY KRATEUAS

(REPRODUCED FROM SIR CHARLES SINGER'S "THE HERBAL IN ANTIQUITY," THE JOURNAL OF HELLENIC STUDIES, 1927.)

[1] A relative of the wild ginger, or Canada snakeroot (*Asarum canadense*), of N. America.

he himself would be poisoned by his enemies, so that, in order to protect himself, he prepared a complicated "antidote," which contained thirty-eight different ingredients, and which, he hoped, would give him general immunity to all poisons.

A little over a hundred years later—from A. D. 54 to 68—the herbalist Andromachus of Crete was physician to the Emperor Nero in Rome. He is especially known, because he, like King Mithridates, was a compounder of antidotes, or, as they came to be called after their royal inventor, "mithridates." The mithridate of Andromachus was even more complicated than the original, and it was to be used against every kind of poison, injury or disease. After Andromachus, the idea of the mithridate became popular, and even up to the end of the eighteenth century, it was still the custom in certain European cities to prepare, once a year, publicly and in the presence of magistrates, a "Theriaca Andromachi," an antidote which contained about 140 ingredients. The writer of this article was recently reminded of this custom when walking along a quaint old street in Moulins, a cathedral city in France, for, in a chemist's shop-window, was a large and beautiful blue-and-white earthenware jar, bearing an inscription indicating that it had contained the "Theriaca Andromachi" prepared publicly at Moulins in the year 1627. The word "theriaca" or "theriac," it may be noted, has given rise, by way of the Old French and Middle English "triacle,"[2] to the modern version "treacle," meaning "antidote," and occurring, for example, in the English common name of a wild fen-land plant, the "treacle mustard," ***Erysimum Cheiranthoides***;[3] the name ***Erysimum*** is itself derived from two Greek words which indicate that the plant is a remedy against loss of voice.

From the time of Krateuas, many herbals have been produced by writers in Italy, Germany, England, and other European countries; and in the first century A. D., various works appeared upon which many of the later ones were based. The earliest of these first century herbals was perhaps that written by Pamphilos, a Greek physician who practiced in Rome. As, however, he apparently described plants which he had never seen, and included many supersitions in his descriptions, his work was not held in great repute.

The most famous and influential of all herbalists is Dioskurides, who became physician to the Roman army in Asia soon after the middle of the first century. Dioskurides traveled widely and was greatly interested in the plants he found, though his interest was mainly "practical," for his actual descriptions of plants were short, compared with the lists of their medical uses. His herbal was, of course, written in Greek; and in compiling it, Dioskurides undoubtedly used the works of previous writers—Hippocrates, Theophrastus, Krateuas, Pamphilos and others. Descriptions of about 500 plants were given; many of these plants were employed as drugs even in the days of Hippocrates, and are still in use—aniseed, belladonna, camomile, linseed and peppermint, for example.

[2] "Triacle," in the sense of "remedy" or "antidote," is employed by Chaucer in the "Canterbury Tales"; commenting upon the Physician's tale, the Host says:

But wel I woot, thou doost my herte to erme,
That I almost have caught a cardiacle.
By corpus bones! but I have *triacle*
Or elles a draught of moyste and corny ale,
Or but I here anon a mery tale,
Myn herte is lost for pitiė of this mayde.

[3] The American common name of this plant is "worm-seed mustard." The term "treacle" is frequently applied in England to the syrupy fluid obtained in refining sugar, *i.e.*, "molasses." In conjunction with brimstone (= powdered sulphur), it forms a nursery medicine, at one time very popular. Readers of Dickens will remember that, in "Nicholas Nickelby," the boys of "Dotheboys Hall" were regularly and frequently dosed with this remedy.

FIG. 4. THE NYMPH DISCOVERY

PRESENTING A MANDRAKE TO THE PHYSICIAN DIOSKURIDES; THE MANDRAKE IS TETHERED TO A DOG AS DESCRIBED IN THE TEXT. (REPRODUCED FROM SIR CHARLES SINGER'S "FROM MAGIC TO SCIENCE," BY THE COURTESY OF MESSRS. ERNEST BENN, LONDON, AND OF MESSRS. HORACE LIVERIGHT, NEW YORK.)

Fig. 4 shows the famous herbalist receiving a mandrake from the nymph "Discovery." The mandrake is a plant around which some very curious superstitions arose, so that it became one of the most frequently illustrated plants of the herbals. There was, in the early days, a very general idea that the mandrake had human limbs, because the forking of the root sometimes suggested a likeness to the human body; this idea is plainly illustrated in Fig. 4, and also in Fig. 5. William Turner, an English physician who lived in the sixteenth century, wrote a famous herbal in which he tells, with great scorn, how "crafty theves," in order to "mocke the poore people," cut and trimmed mandrake roots to make them look like "little puppettes"; in this way, the idea of the human form of the mandrake was spread and encouraged. According to Theophrastus, mandrake leaves mixed with meal were good for wounds, and the roots, treated with wine or vinegar, for many complaints, including sleepless-

ness. The mandrake's sleep-inducing properties are illustrated by Lucius Apuleius in his famous story, "The Golden Asse"; he tells of a boy, who, having drunk a strong draught of mandrake in wine, fell down in such a deep sleep that his schoolmaster and his mother, and the servants of the household, in ignorance of what he had drunk, thought he was dead; and he was accordingly buried.

The directions given in the old herbals for the uprooting of the mandrake are very careful and minute, because it was supposed to be a plant of such great virtue. The plant was to be "earnestly delved" around with an *ivory* staff, until its "hands and feet" were uncovered; then a hungry dog was to be tethered to the root, and a piece of meat put just out of the dog's reach, so that in straining for the meat, he necessarily jerked up the root. It was popularly believed that whoever uprooted a mandrake would die as a result, and so a dog was sacrificed for this purpose; it will be noted that the dog is tethered to Discovery's mandrake in Fig. 4, and he is also shown in Fig. 5, an illustration from an early printed herbal, produced in Rome about 1484.

It must be remembered that the mandrake of the old herbals—and of the Bible also, for it is mentioned both in Genesis and in Canticles[4]—is not the same as the plant which is sometimes called mandrake in America, and which grows wild in large quantities in the woodlands east of the Mississippi River. This plant is more commonly called "May-apple," and it is a relative of the barberry frequently cultivated in shrubberies; it is widely used in modern medicine as a stimulant for the liver and for dyspepsia; whereas the original mandrake is a member of the potato family, and is not now used medicinally.

[4] Genesis, xxx, 14; Canticles, vii, 13: inferences as to the aphrodisiac properties of the herb, a belief in which is still held in the East.

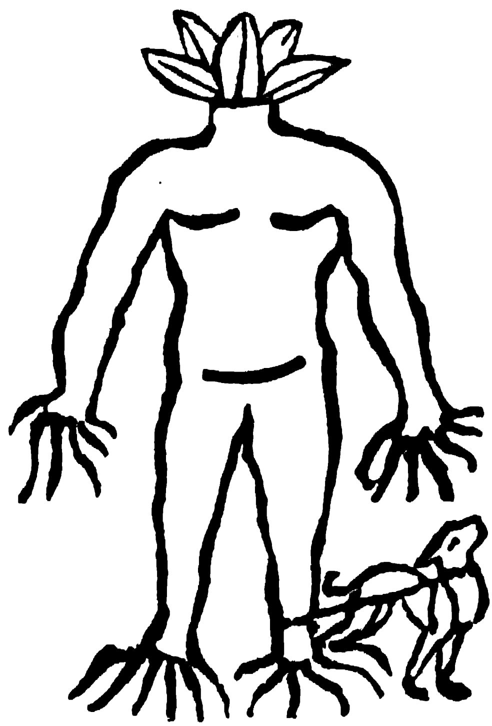


FIG. 5. A TRADITIONAL REPRESENTATION OF THE MANDRAKE

FROM AN EARLY ITALIAN PRINTED HERBAL (ABOUT A. D. 1484). (REPRODUCED FROM SIR CHARLES SINGER'S "FROM MAGIC TO SCIENCE," BY THE COURTESY OF MESSRS. ERNEST BENN, LONDON, AND OF MESSRS. HORACE LIVERIGHT, NEW YORK.)

The Dioskuridean herbal has been the main source from which later works of the same kind have been derived. Many versions were written in Greek—the "Juliana Anicia" manuscript, containing copies of the drawings of Krateuas, is one of the most famous of these. In the sixth century, Latin versions appeared; and one of these, in about A. D. 1000, gave rise (combined with another herbal to which reference will be made later) to an Anglo-Saxon herbal. The work of Dioskurides thus became widely known in Europe; and it also, through translations into Arabic, Syriac, Persian and Hebrew, came to be used in Oriental countries as well.

It has already been noted that "Marius the Epicurean" saw the physician Galen at the temple of Aesculapius, near Pisa; it is now necessary to discover something of this great man and his work. Galen was born in A. D. 130 at Pergamum in Asia Minor; he studied at the medical school in his native city, and later at Alexandria. When he was twenty-eight, he had a serious illness, caused, apparently, by eating too much fruit; he himself tells us that he owed his recovery to the god Aesculapius, whose grateful servant he henceforth became—that, of course, explains why Marius saw him at an Aesculapian temple. In A. D. 161, Galen went to Rome, where he soon made a name for himself and developed so large a private practice that other physicians were jealous of him, and he had to leave Rome for a while; when he returned, he settled down to the writing of books on many subjects—he is said to have been the author of nearly 400 works. One of these was an herbal so systematic and complete that for many years no entirely new herbal appeared; indeed, with Galen, Greek medical science may be said to have come to an end.

Galen's Greek herbal, like that of Dioskurides, was translated into Latin. Besides these "derived" Latin herbals, there were one or two "native" works, of which that of Pliny is the best known. Pliny was a contemporary of Dioskurides, and about A. D. 60, he produced an extensive Latin work on natural history, including a lengthy account of "Remedies derived from the Garden Plants." Pliny apparently collected, from all sorts of sources, ideas on the nature, origin and uses of plants. So industriously did he work at his collecting and compiling from other people's books that he considered even taking a walk to be waste of time; but his writings were so uncritical and unscientific that they were of no real value. They were, however, widely read, copied and translated for centuries, with the result that a large part of them has gradually passed into folk-lore, and the gipsy fortune-teller of to-day, as Sir Charles Singer notes, is still reciting charms and spells that Pliny himself borrowed from the works of the old Greeks, written centuries before his time.

The most important Latin herbal is that of Apuleius. It is not known who Apuleius was; he was certainly not the Lucius Apuleius who wrote "The Golden Asse," for that author lived about the same time as Galen, in the second century A. D., and the Apuleian herbal did not appear until the fourth century. The original has been lost, but numbers of later versions—which are illustrated—are still in existence. Associated with a Latin version of the Dioskuridean herbal, the Apuleian herbal was first translated into Anglo-Saxon about A. D. 1000, and later about 1120. This later translation was written at the Abbey of Bury St. Edmunds by one of the monks; and it is of great interest, because some of its flower pictures are very natural and of considerable beauty, and were evidently painted by a lover of plants. This Bury St. Edmunds herbal is still in existence, and may be seen in the Bodleian Library, at Oxford.

Versions of the Apuleian herbal were copied and recopied continually; and, when printing was invented, this herbal was one of the first books to be produced in print. Its original illustrations were also reproduced, as wood or metal "cuts." As will be seen from Figs. 5 and 6, they were rather crude; but generally they showed the plant as a whole, including its roots, which was, of course, natural in an herbal, for from the herbalist's point of view it was often the root of a plant which had special "virtues." Another feature of these illustrations is that representations of the animal whose bites or stings were supposed to be cured by the use of a particular plant, were often included with the drawing of the

FIG. 6. A REPRESENTATION OF PLANTAIN

THE WHOLE PLANT, WITH A SNAKE AND SCORPION. FROM AN EARLY ITALIAN PRINTED HERBAL (ABOUT A. D. 1484). (REPRODUCED FROM MRS. ARBER'S "HERBALS," BY THE COURTESY OF THE CAMBRIDGE UNIVERSITY PRESS.)

plant itself; Fig. 6, for example, shows the plantain, accompanied by a snake and a scorpion, against the attacks of which it was supposed to be an antidote.

After the invention of printing, many herbals appeared; some were based directly on the old manuscripts, others were translations of manuscripts into French or German, and some, in various languages, were more or less original. The result was that the printed herbal became wide-spread in Europe—in Germany, France, Italy, the Netherlands, Switzerland and England.

The first printed English herbal was that published in 1525 by "Rycharde Banckes" of London. We do not know who was the real author of this very charming little book; but, whoever he was, he was evidently more poetically than scientifically inclined, as his remarks concerning the herb rosemary indicate. Amongst the many "virtues" of rosemary we find the following:

"Take the flowers thereof and make a powder thereof and binde it to thy right arme in a linnen cloath and it shale make theee light and merrie."

"Boyle the leaves in white wine and washe thy face therewith and thy browes and thou shalt have a faire face."

"Also put the leaves under thy bedde and thou shalt be delivered of all evill dreames."

"Make thee a box of the wood of rosemary and smell to it and it shall preserve thy youth."

The writer of Banckes's herbal evidently drew his information about rosemary from an old manuscript which was sent to Queen Philippa of England (the wife of Edward the Third) by her mother, the Countess of Hainault. This fourteenth century manuscript records an old tradition (not, however, mentioned by Banckes) which is still held by many country people in England today, namely that rosemary "passeth not commonly in highte the highte of Christe whill He was man on Erthe." It is said that the Countess of Hainault not only sent the manuscript to her daughter, but that she sent the first plants of rosemary to England, too. This herb apparently became very costly in the reign of Charles the Second, when it was used, on account of its sweet smell, to ward off infection of the plague, which raged in London in 1665.

Banckes's herbal soon became very popular, and during the next thirty years it was reprinted many times, by different publishers, under different titles.

In 1526, there appeared what is perhaps the most famous of the early

printed herbals, namely, "The Grete Herball." This was a translation of a French printed herbal, which was itself most probably derived from a Latin manuscript.

"The Grete Herball" contains a good deal of information which is not strictly herbal; for example, it is pointed out (on the authority of Galen) that bathing is unwise, for "many folke that hath bathed them in colde wa(ter) have dyed or they came home." But this work at least marks a great advance on the methods of the old Greek herbalists and root-diggers, who, it will be remembered, hedged their trade around with secrecy and superstition; for "The Grete Herball" exposes the often-practiced frauds of the herb-sellers—the mandrake superstition, for instance, is firmly rejected.

Some of the names given to British plants in this herbal are both picturesque and interesting: the common arum is called "prestes hode"; duckweed, "lentylles of the water"; and wood-sorrel, "alleluya." The last two names are of interest, because, as we have seen, "The Grete Herball" was a translation of a French herbal; and duckweed and wood-sorrel are commonly called "lentilles d'eau" and "alleluia," respectively, in France to this day." "Alleluia" is so named because it flowers about Easter-time, when the "Alleluia" reappears in the church services, after the long Lenten season, during which it is not used.

There were various reprints of "The Grete Herball," but the next new British herbal proper was written by William Turner, between 1551 and 1568. Turner was a clergyman of the "reformed" faith, but he was continually getting into trouble with both parties in the church, and periodically he had to leave England in consequence. He traveled a good deal in Europe, and took a medical degree in Italy, where he also studied botany. He wrote several smaller botanical works before his herbal; it was in the latter that he treated the mandrake story with scorn, as already mentioned.

Then in 1597 appeared John Gerard's "Herball or Generall Historie of Plantes," a book which has made Gerard's name famous, though he does not in the least deserve his reputation, for he merely adopted and completed another writer's unfinished translation of a continental herbal. "Gerard's Herbal" is illustrated by a large number of pictures, most of them borrowed; but one of his own original illustrations is the first published representation of the potato plant. One of the borrowed pictures is an absurd and amusing one of the "Goose Tree," or "Barnakle Tree," which is reproduced in Fig. 7. Gerard was certainly not a reliable observer, for he declared that he had actually seen a goose tree on a "Small Ilande in Lancashire." His description of it is very circumstantial; he says that branches of old and rotten trees and broken pieces of ships produced whitish shells, inside each of which, in course of time, a bird was formed. When the birds were perfectly shaped, the shells opened and the birds fell out into the sea. The myth of the "Barnakle Tree" was apparently wide-spread, and was believed at least as long ago as the twelfth century; the "barnacle geese," indeed, caused the church authorities considerable difficulty, because there was doubt whether they were fish, or flesh, or neither, and whether they might, or might not, be eaten during Lent.

Gerard had a herb-garden containing 1,000 different herbs, in what is now Fetter Lane, in London. He was undoubtedly a lover of his garden flowers, and of wild flowers also, for one of the most interesting features of his herbal is his account of the plants which he found in the lanes and fields and hedges of "Piccadilla," and other places now overrun by the busy city of London.

John Parkinson, who believed that Adam was inspired with a knowledge of

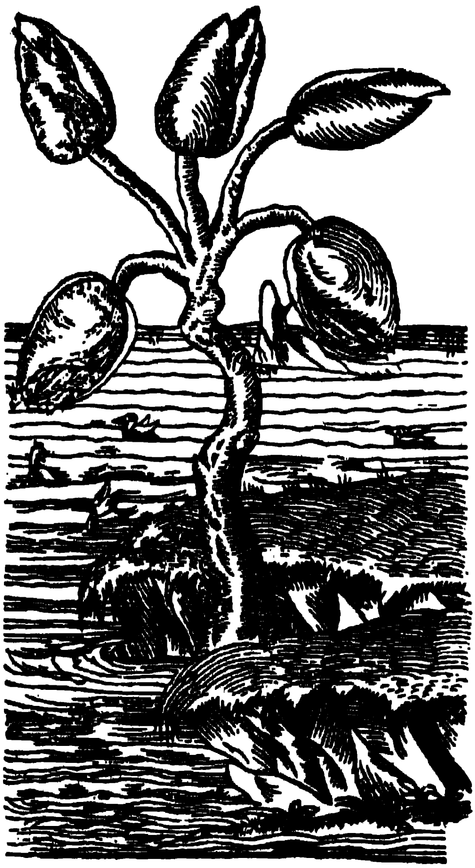


FIG. 7. THE "GOOSE TREE" OR "BARNAKLE TREE"

AS FIGURED BY GERARD, IN THE "HERBALL" OF 1597. (REPRODUCED FROM MRS. ARBER'S "HERBALS," BY THE COURTESY OF THE CAMBRIDGE UNIVERSITY PRESS.)

the uses of all herbs, was the next British herbalist after Gerard; he also had a famous herb-garden in what is now a very busy area in London.

Some of the superstitions which became attached to various herbs have already been mentioned. We must now examine some very absurd ideas about plants which were held even as late as the sixteenth and seventeenth centuries, and which were very popular—one writer, indeed, defended them on the ground that they were "pleasant," even if untrue. These ideas may be considered under two headings—"astrological botany" and "the doctrine of signatures."

Astrological Botany

In Babylon, as long ago as 3,000 years before the birth of Christ, men came to believe that they, and all other animals, and all plants and minerals were under the influence of the planets. Each plant was held to be governed by some particular star, which caused the seedling to push out of the ground when the seed germinated. A belief in the influence of the moon upon plants is shown in Pliny's "Natural History" (written about A. D. 60), where we read that the Druids in Britain gathered the mistletoe for medical purposes when the moon was six days old. In most cases it is impossible to discover why an herb was associated with one planet rather than with another; but in some cases, the shapes of the leaves or fruits suggested an association—with the moon, for example, as in the case of the fern "moonwort," shown at the right-hand side of Fig. 8. In the seventeenth century a belief in astrological botany was very wide-spread in England, the great advocate of the subject being Nicholas Culpeper, who lived between 1616 and 1654. Culpeper was a "physician-astrologer," not at all popular with the more orthodox members of the medical profession—which is not surprising, for he called them "a company of proud, insulting, domineering Doctors"; he also claimed that his methods were far superior to those of previous astrological herbalists, being guided by reason, whereas their writings were "as full of nonsense and contradiction as an Egg is ful of meat." He wrote a book called the "Physicall Directory," which was reprinted many times; the 1653 edition was described as a discourse showing how "a man may preserve his Body in Health; or Cure

FIG. 8. "LUNAR HERBS"
AS FIGURED BY GIAMBATTISTA DELLA PORTA IN 1591. (REPRODUCED FROM MRS. ARBER'S "HERBALS," BY THE COURTESY OF THE CAMBRIDGE UNIVERSITY PRESS.)

himself, being Sick, for three pence Charge, with such things only as grow in England, they being most fit for English Bodies." In "Rewards and Fairies," Mr. Rudyard Kipling tells a story entitled "A Doctor of Medicine," which gives a delightful idea of the "very simple soul" combined with "a high courage tempered with sound and stubborn conceit" which Culpeper must have been. He met with much criticism, particularly from one William Cole, who wrote very scathingly of him soon after his death. Cole's arguments against astrological botany were very ingenious; he contended that since plants were created on the third day, and the sun, moon and stars on the fourth day, there can be no dependence of plants upon the planets: for "Plants were, even when Planets were not."

THE DOCTRINE OF SIGNATURES

This was a mystical idea which was, to a certain extent, combined with astrological botany; according to it, plants were "signed," so to speak, by their form and color and scent, in such a way as to indicate what are their healing properties; Fig. 9 shows plants, the form of whose fruits or flowering spikes suggests that they are remedies for scorpion stings.

A belief in signatures was indicated in the old botanical writings long before it was definitely stated by Paracelsus, a German alchemist, born in 1493. Paracelsus was the son of a doctor, and he himself became a professor of medicine at Basle, where he publicly burnt the works of Galen and other physicians. He had considerable influence on the study of medicine, for he was an able chemist, and pointed out the need for applying chemistry to medicine. Paracelsus was extremely boastful and violent-tempered, and consequently found it impossible to remain long in any one place; he wandered about from country to country, now prosperous and famous, now poor and disgraced. Robert Browning's poem "Paracelsus" gives a vivid idea of his strange career.

The doctrine of signatures was developed by a Neapolitan scientist and writer named Giambattista Della Porta, in 1588. Porta not only believed that plants were "signed" by their form and growth, color and scent; he also held that plants with short or long lives could be used to shorten or lengthen human lives, and that the plants of a particular area were intended to cure the diseases of the people living there. This last idea is interesting, because it led to the discovery of "salicin," used in the treatment of rheumatic fever; this substance occurs in the bark of the willow, which of course grows by water or in damp places likely to induce rheumatism.

The great English advocate for the doctrine of signatures was William Cole, who, however, as we have already seen, ridiculed the idea of "astrological botany." William Cole was born in 1626, at Adderbury near Oxford; he died

FIG. 9. "HERBS OF THE SCORPION"
AS FIGURED BY GIAMBATTISTA DELLA PORTA IN 1591. (REPRODUCED FROM MRS. ARBER'S "HERBALS," BY THE COURTESY OF THE CAMBRIDGE UNIVERSITY PRESS.)

when he was only thirty-six, a few years after writing a rather famous book, "Adam in Eden." In this work, he shows how the "wall-nut" has the "perfect Signature of the Head"; the kernel, for example, "hath the very figure of the Brain, and therefore it is very profitable for the Brain, and resists poysons; For if the Kernel be bruised, and moystened with the quintessence of Wine, and laid upon the Crown of the Head, it comforts the brain and head mightily."

Cole was much puzzled by the fact that many herbs with undoubted medicinal virtues were left "unsigned"; he concluded that some were signed in order to put man in the right way in his search for remedies, and that others were left without signatures to encourage him to research and find out their properties for himself.

Another supporter of the doctrine of signatures in England was Robert Turner, the writer of "The Brittish Physician" (1664), in which is mentioned the

Jewish tradition concerning the herbals of King Solomon. Robert Turner, unlike William Cole, was a firm believer in astrological botany.

Conclusion

As Mr. Kipling says, in "Rewards and Fairies,"

> Anything green that grew out of the mould
> Was an excellent herb to our fathers of old.

But—

> Half their remedies cured you dead—
> Most of their teaching was quite untrue—

and there is little wonder that under the influence of mystical ideas like astrological botany and the doctrine of signatures, herbal remedies and the trade of the wandering herbalists, or "green men," as they were called, fell into disrepute.[5]

General public interest in medicinal herbs has, however, been revived within the present century as a result of several factors, one of which was the great war of 1914–18. The growing of drug-yielding herbs, at the outbreak of the war, was largely in the hands of Germany and Austria; and in order to keep up supplies of various drugs, in England more particularly, it was necessary that the plants providing them should be, as far as possible, cultivated and prepared in the country. Various associations for these purposes were therefore formed, and, in England at least, a useful, and, it is to be hoped, a lasting interest in this medical aspect of wild and garden plants was thus encouraged.

[5] It may interest American visitors to England to be reminded that the itinerant herbalists gave their name to various inns up and down the country. "The Green Man" at Ashbourne, near the famous Dove Dale, is a notable example.

Another factor which perhaps stimulated a good deal of interest in medicinal herbs, more particularly in America, was the appearance of Mrs. Gene Stratton Porter's novel "The Harvester." The Harvester, it will be remembered, was an American herb-cultivator, one of his "crops" being ginseng, the root of which has tonic properties; it has much the same shape as a mandrake root, and indeed there is a Chinese legend of the ginseng plant very similar to the early European story of the mandrake.

The foregoing sketches from the "History of Medical Botany" will indicate how this utilitarian aspect of an interest in plants has passed through the various stages of observation, tradition, guesswork and superstition, and finally emerged as a scientific study. A knowledge of chemistry, as Paracelsus even in his day realized, is essential to the treatment of disease; and exact chemical research has now revealed the valuable curative properties of many herbs and plants, as in the case of the drug "salicin," already mentioned, and also in that, for example, of the volatile oil obtained from the wild carrot and found to be of use in the treatment of asthma. This is an interesting case, for the celebrated John Wesley, in a small treatise entitled "Primitive Physic, or an Easy and Natural Method for Curing Most Diseases" (1769), advised sufferers from asthma to "live a fortnight on boiled Carrots only."

Herbal treatment is, in fact, no longer an empirical matter; being founded, as it now is, on scientific research and observation, there is every likelihood that herbs will be increasingly utilized once more as healers of the physical ills of mankind.

EINSTEIN'S THEORY AND RATIONAL LANGUAGE[1]

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Introductory Remark

It is a fact that even highly educated laymen have very little understanding of the relativity theory. What largely contributes to this is that in expounding the theory phrases are used to which attaches a mystical meaning, or which convey no meaning at all, in ordinary language. These phrases are the expressions "fourth dimension" and "curved space." It is difficult to do without them in an interpretation of the theory. Yet this is not only feasible but even renders it better intelligible. The term "four dimensions" seems to be unavoidable in describing Minkowski's "World" which plays a most important part in the relativity theory. The following characterization of this author's idea, however, shows that his "world," which remains an enigma to the layman by reason of that confusing expression, becomes understandable to him when its description keeps clear of it. The same holds true of the bewildering term "space curvature" in explaining the rôle of the Euclidean geometry in the general relativity theory.

Minkowski's World in the Relativity Theory

An aggregate of elements of the same kind is a continuum if their sequence is uninterrupted, if one element is contiguous to another or others. A line is a continuum whose elements are points. A point in a line touches two other points. A surface and the space, too, are continua with points as elements. A point in a surface, however, adjoins an infinite number of other points, and in space a still greater infinity of other points. There are other differences between these three continua. The most important one relates to the location of a point.

Mathematicians and physicists are very often confronted with the necessity of locating a point in one of the three continua. A point in a line is determined by its distance, x_1, from another point in it fixed arbitrarily. No other measurement is needed than that of this distance to find the point sought. A line is therefore a continuum of one variable, x_1. To obtain a point in a surface, two straight lines in it intersecting each other —it is convenient but not necessary to make the angle of intersection a right one—are selected arbitrarily. Any point in the surface is then given when its distances, x_1 and x_2, from the two lines are known. Two measurements are needed in this case. A surface is therefore a continuum of two variables, x_1 and x_2. To locate a point in the space, finally, we fix arbitrarily three straight lines in it which intersect each other in one point, usually—but not necessarily—at right angles. Any point in the space can be found through its distances, x_1, x_2, x_3, from the three lines. The space is a continuum of three variables, x_1, x_2, x_3.

Time is an aggregate of equal elements, of instants. There is no break between them; one instant is always preceded by another and followed by still another. Time is therefore a continuum. If one instant in it is fixed arbitrarily, any other instant is determined through the interval, t, between it and the fixed

[1] Rationality and greatest possible expressiveness characterize the Model Language, the idea of which was broached by the writer in Scientific Monthly, April, 1929.

instant. This interval is measurable and nothing else needs to be measured to find the instant sought. Time is therefore a continuum of one variable, t.

In the prerelativistic era space and time appear disconnected, independent of one another. This is expressed in the Galilei-transformations: $x' = x - vt$; $t' = t$. We see from these equations that in going over from one system, K, into another, K', which is in motion relative to K, a spatial distance changes, but a time interval remains the same. The special relativity theory has divested time of this independence. The equation, $t' = (t - xv/c^2)/q$, which is one of the Lorentz-transformations figuring in the relativity theory and wherein $q = \sqrt{(1 - v^2/c^2)}$, indicates that a change of the spatial distance x of the system K conditions a change of the time interval t' in the system K'. Time stands in relation to space.

This principle of interdependence of space and time is clearly embodied in Minkowski's "World." It is represented by the totality of the physical events in the universe, and time and space are not separate continua in it, but closely knit together, forming an indissoluble unity, the space-time continuum. That space and time do not exist each by itself, alone, is obvious. A certain point is always found at some instant, and a certain instant is always noticed at some point. An event always occurs both in some point and at some instant. This means that space and time are not severable and one always coexists with the other. The mathematician Hermann Minkowski was the first to emphasize this inseparableness of space and time. In a lecture before the Physicists and Physicians at Cologne on September 21, 1908, he prophetically expressed in the following words the idea that space and time will be treated in physics always as coexistent: "From this hour on shall space by itself and time by itself completely sink down to shadows, and only a sort of union of both shall preserve independence."[2]

Space and time, accordingly, are to be considered jointly in describing the physical events. Indeed, an event always comprises both a spatial point and an instant. It is determined only when both are given. The united space-time is composed of equal elements, of events, and forms a continuum since every event is contiguous to other events. The space-time continuum has four variables. Minkowski calls an event a "world-point." It is determined through three spatial variables and one time variable. A series of consecutive world-points constitutes a "world-line."

The chief advantage accruing for the relativity theory from Minkowski's union of space and time is that in developing this conception he devised a method of making the time variable play formally in mathematical calculations exactly the same part as any one of the space variables. He showed that if to the time variable is given the value $tc\sqrt{-1}$ instead of t, and $x_4 = tc\sqrt{-1}$, then x_4 enters into all calculations in the same way as a space variable. The four variables of the space-time continuum are then simply x_1, x_2, x_3, x_4, and the last one relating to time does not differ from the other three as far as algebraic operations are concerned. This makes it possible to apply in calculations referring to the space-time continuum of four variables the same Euclidean geometrical methods as are used for the space continuum of three variables. A distance between two points in the latter, for instance, is given through the equation $d^2 = x_1^2 + x_2^2 + x_3^2$. In the same way the distance between two world-points is expressed through the analogous equation $d^2 = x_1^2 + x_2^2 + x_3^2 + x_4^2$. Through this device, namely, $x_4 = tc\sqrt{-1}$, the

[2] Literal translation from German; see "Model Language," No. IV, SCIENTIFIC MONTHLY, April, 1929.

mathematics of the relativity theory has been greatly simplified and clarified. Max Born even states that "without this mathematical auxiliary the general relativity theory would be unconceivable." This statement agrees, on the whole, with Einstein's remark that "without the important idea of Minkowski the general relativity theory would, perhaps, have remained in its infancy."

Rational Language and Intelligibility of the Relativity Theory

The preceding presentation of Minkowski's "World" could have been given, as far as language is concerned, much more conveniently through the use of the term "dimension" and its derivatives. Yet they have been avoided advisedly. For the layman the expressions "four dimensions," "four-dimensional" comprise something weird, savor of mysticism and are confusing. "Dimension" does not mean the same in ordinary as in mathematical language. In the former it signifies one of the three directions of a body represented by length, breadth and thickness, that is, by three straight lines perpendicular to each other in one point. The layman therefore can not but consider a fourth dimension as something impossible. There can not be a straight line perpendicular to three other straight lines in one point in which they intersect each other at right angles. For this reason a layman has the feeling as though a cabalistic atmosphere pervaded a system in which four dimensions are figuring, as is the case with the relativity theory.

Nothing mysterious attaches to the expression "four dimensions" for the mathematician. For in geometry "dimension" signifies any direction in a body, not only one of the three represented by length, breadth, and thickness. A body has therefore an infinite number of dimensions. In algebraic operations "dimension" means simply a quantity susceptible of change, a variable. Minkowski's "World" can be made intelligible to the layman by replacing the word "dimension" with the noun "variable" in describing it, as we have seen above. Yet the mathematician can not do without the former because he needs quite frequently also the derivative "dimensional," and particularly the adjective "four-dimensional," pertaining to four dimensions. Owing to the irregularity of our languages such adjectives can not be formed from the noun "variable." For this reason a derivative of the noun "dimension" has to be used where one from the noun "variable" would suffice and be clearer for the layman. The adjective "pertaining to four variables" is too inconvenient in mathematical writings, rendering the adjective "four-dimensional" all but indispensable. If our languages permitted to construct in the same way the corresponding derivative from the noun "variable," the adjective "four-dimensional," obscure to the layman, could be avoided.

The preceding considerations furnish a striking illustration for the usefulness of a rationally constructed language, the Model Language.[8] In Arulo, the basis of the Model Language (not to be confounded with International Language which cares little for strict rationality), the two nouns discussed above are: dimensiono, dimension; varieblajo, a variable. Adjectives are formable from both in the same way: quar-dimensional, four-dimensional; quar-varieblajal, pertaining to four variables. The last adjective is the one which is needed for a smooth presentation of Minkowski's "World" but does not exist in a convenient form in the natural languages. The relativity theory can be explained to a layman in Arulo better than in a natural language and to mathematical student at least as well.

[8] Scientific Monthly, April, 1929; *Mod. Lang. Jour.*, February, 1930.

Euclidean Geometry in the Relativity Theory

Similar considerations obtain regarding the expression "space curvature," as the following discussion shows. A straight line is indeterminable in a gravitational field. For the means of ascertaining it is a light ray and the latter is bent in such a system. Nor can a length be measured in a gravitational field because it varies in it from place to place. Euclidean geometry being based upon the conception of the straight length becomes therefore useless in describing the natural phenomena in a gravitational field. Nevertheless the validity of the Euclidean geometry is just as intact as it ever was before the general relativity theory. This can not be emphasized strongly enough because the relativistic literature, partly through vague or emotional language, has created the impression that the relativity theory has overthrown the Euclidean geometry. "The whole edifice of the Euclidean geometry is tottering," remarks Born, and "a single man, Albert Einstein, destroyed confidence in the evidence of the Euclidean geometry" according to Weyl. Such utterances by great authorities are bound to mislead the layman into believing that the relativity theory has entirely invalidated the methods of Euclid. Nothing is further from the truth than this. That geometry lost as little of its validity by being inapplicable to large parts of the space in a gravitational field as by its inapplicability on a large scale, discovered by Gauss, in surveying a tract of land of an uneven surface. According to Gauss the surveyor has to divide the surface into small parts. He then measures these by Euclidean methods and adds the results obtained, thus ascertaining the area of the whole tract. Gauss showed a way of treating such a surface geometrically without using Euclidean principles. This way led to the development of the non-Euclidean geometries of Riemann and others. Only such a geometry can be applied to extensive parts of the space in a gravitational field. This does not at all mean that Euclidean geometry is not valid.

The quality of the space in a gravitational field rendering Euclidean geometry inapplicable to extensive parts of it has been designated as "space curvature." This was an unfortunate expression. It has produced no mean confusion. It has enshrouded the relativity theory with a cabalistic veil and has furnished grist to the mill of the mystics and abettors of the modern tendency to elevate the unconscious, the vague, the unreasonable above the conscious, the clear, the rational. The meaningless confusing phrase "space is curved" can and should be avoided in treating the relativity theory. Space is not "curved" outside of a gravitational field nor inside of it. Space is only non-Euclidean here, that is, Euclidean geometry is inapplicable to it on a large scale. But minute parts of it admit very well of treatment by that method. The use of the bewildering phrase "space curvature" is due to the inadequacy of the natural languages. A noun is needed to designate the above-mentioned quality. In German one can not form from the adjective "uneuklidisch" a noun corresponding to the English substantive non-Euclideanism formable from the adjective non-Euclidean. German authors, therefore, used the expression "Raumkrümmung," space curvature, to denote that quality which, in the end, is due to a straight line being indeterminable in a gravitational field. English writers followed their example although they did not need to do this. In a rationally constructed language such perplexing words can always be avoided in expounding the relativity theory. Thereby it becomes free of all mysteriousness and can be made comprehensible to the educated layman.[4]

[4] This article, just as "The Fundamentals of the Relativity Theory" (Scientific Monthly, January, 1932), is an extract of a book to be published in the future.

SAILORS, COCONUTS AND MONKEYS

By Dr. S. A. SCHELKUNOFF

BELL TELEPHONE LABORATORIES

At one time or another probably every reader has been puzzled by some problem which belongs to a branch of mathematics, fascinating in itself, but very little known to laymen. Thus in recent days, there has been a renewal of popular interest in the problem of the sailors, coconuts and monkeys.

It seems that five sailors, wrecked on a South Sea island and in search of food, knocked down enough coconuts to last them for months but were too tired to divide them into equal shares on the same day. That night one of the sailors woke up and decided to take his share; but on dividing the supply into five equal piles, he discovered that one coconut was left over. In order to make his problem simple, he threw the extra coconut to the monkeys and took one of the piles away. Later on, another sailor awoke and decided to take his fifth. Not knowing that the first sailor had already taken his share, he divided the supply into five equal parts, but found one coconut left over. Like the first sailor, he threw it to the monkeys and took what he thought belonged to him. As the night wore on, the remaining sailors did the same, always finding themselves in the predicament of having an extra coconut and always disposing of it in the same manner. In the morning the five sailors divided what was left into five equal piles, and this time they accomplished the division without having to throw away any coconuts. The problem is to find how many coconuts there were at the beginning.

This problem is one in Diophantine Analysis, the branch of mathematics dealing with the solution of systems of equations in which the number of unknown quantities exceeds the number of equations and the solutions are required to be in integers. The analysis is named for Diophantus, a Greek mathematician, who seems to have been the first to become interested in such problems. One of the most brilliant of mathematicians, Diophantus lived about 250 A. D., but there is definitely known about him only that he died at the age of 84, from his epitaph reading: "Diophantus passed one sixth of his life in childhood, one twelfth in youth and one seventh more as a bachelor; five years after his marriage was born a son who died four years before his father, at half his father's ultimate age."

The problem of the coconuts can be set up as an equation of the type $ax + by = c$. Of course there is no trick in solving this equation if x and y are unrestricted, for one can choose any value whatever for one of these unknowns, substitute it in the equation and solve for the other unknown, thus obtaining an indefinite number of solutions, one for each choice. When x and y are required to be integers, the solutions, though far less numerous in any particular range of values, may still be indefinite in total number. If, however, x and y are required to be not only integral but positive, the equation may possess only a finite number of solutions or even none at all (Fig. 1).

It can be shown that, if $x = p$ and $y = q$ constitute an integral solution of the equation, all the other integral solutions can be obtained from this by substituting all the integers successively for t in the formulas $x = p + bt$ *and* $y = q - at$. Thus the problem can be reduced to

that of finding any one solution to the original equation.

Diophantus solved each equation by a method peculiar to it; in common with most of the ancient mathematicians, he was interested in obtaining a specific solution rather than in developing general methods of procedure. General methods have since been developed for handling the simpler types of Diophantine problems, including that under which the problem of the coconuts falls. There are many more types, however, for whose solution general methods are not even to-day available. It is interesting, therefore, to consider a special method of solution such as Diophantus might have used for this problem, for it illustrates in a simple way the homely modes of procedure upon which mathematicians must still rely in many more complicated kinds of Diophantine problems.

Roughly this mode of procedure may be described as paring down the equation until a solution can be obtained by inspection. The paring down is accomplished by applying the theorem that every integer, and thus each quantity in the equation, can be expressed as the product of one and only one set of prime factors. Thus if the coefficients on one side of the equation are observed to have a number d as a factor, the other side must also have this factor—if not in its coefficients, then in its unknowns, since the equation asserts that both the sides are the same number. The unknown can then be replaced by d times a new unknown, and d can be cancelled from both sides of the equation. By successive application of this device, the coefficients of the equation in the new unknowns are made small enough to permit a solution by inspection. The values of the original unknowns can be obtained from the solution for the new by multiplying the latter by such factors as were cancelled out. The detailed solution of the problem of the coconuts by this method is shown in Example I.

There are two general methods for finding Diophantine solutions of linear equations such as $ax + by = c$. One employs continued fractions, and the other makes use of notions from the Theory of Numbers.[1] In the latter method the equation is written $ax \equiv c \pmod b$, which is read "ax is congruent to c modulo b," the mathematician's way of saying that $ax-c$ is divisible by b without remainder.

A Diophantine problem may offer not one but several simultaneous equations for solution. Such a problem is that of determining the numbers of those years in which Easter Day falls on a given date, which is reducible to the problem

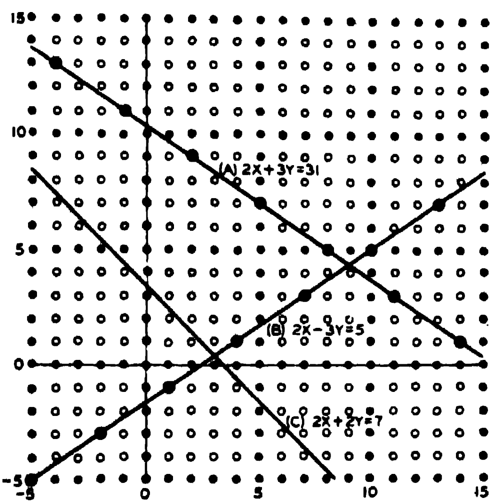

FIG. 1. FINDING THE INTEGRAL SOLUTIONS TO AN EQUATION IN TWO VARIABLES CORRESPONDS TO FINDING THE POINTS WITH INTEGRAL COORDINATES THROUGH WHICH THE GRAPH OF THE EQUATION PASSES. IN THE ABOVE GRAPHS OF THREE LINEAR EQUATIONS, IT CAN BE OBSERVED THAT ONE (A) HAS ONLY A FINITE NUMBER OF SOLUTIONS IN POSITIVE INTEGERS, ANOTHER (B) AN INFINITE NUMBER, AND THE THIRD (C) NO INTEGRAL SOLUTIONS EITHER NEGATIVE OR POSITIVE.

[1] For the former consult G. Chrystal's "Algebra," Vol. II, page 473; and for the latter any elementary treatise on the Theory of Numbers, under the heading "Linear Congruences."

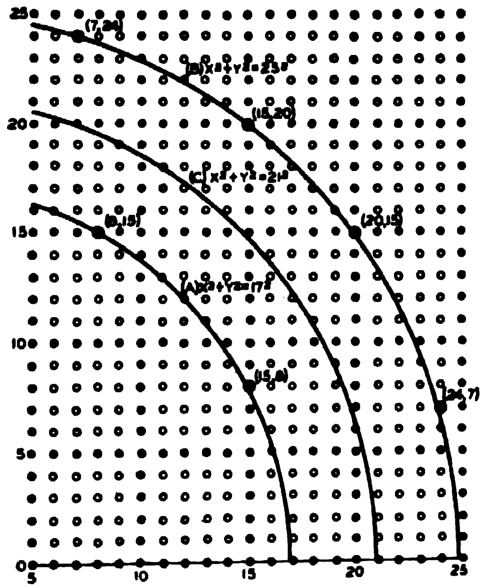

FIG. 2. THERE MAY BE (A) ONE PAIR OF INTEGERS, (B) SEVERAL PAIRS OF INTEGERS, OR (C) NO PAIRS OF INTEGERS, THE SUM OF WHOSE SQUARES IS A GIVEN SQUARE.

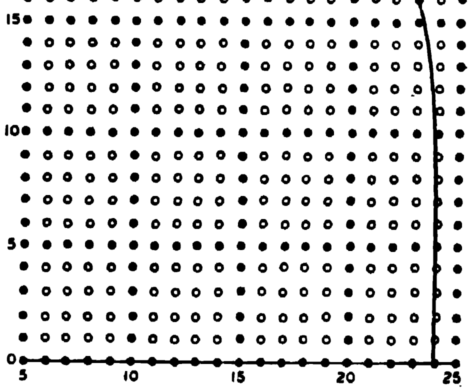

FIG. 3. IT IS STRANGE BUT TRUE THAT THE ENTIRE FAMILY OF CURVES OF THE TYPE $x^4+y^4=z^4$, OF WHICH ONE MEMBER IS SHOWN ABOVE, PASS THUOUGH NO POINTS WITH INTEGRAL CO-ORDINATES.

of solving the six equations with eleven unknowns shown as Example II. Diophantine equations may also be quadratic or of even higher degree. Thus one may wish to find two integers, the sum of whose squares is the square of another integer (Fig. 2). Some solutions can be easily guessed, and all the solutions can be obtained with the aid of certain formulae, as shown in Example III. For the solution of equations of higher degree than the second, no general methods have yet been discovered.

Perhaps the most famous problem in Diophantine Analysis is that known as "Fermat's Last Theorem," after the French mathematician who first stated it, without proof, to the effect that the equation $x^n + y^n = z^n$ can not be solved in integers if n is greater than 2 (Fig. 3). Euler proved the theorem for $n=3$ and $n=4$; Dirichlet for $n=5$ and $n=6$; G. Lamé for $n=7$; and Kummer for many other values. The problem has never been solved with complete generality, although numerous and handsome prizes have been offered by various scientific societies for the complete solution, and new branches of mathematics have been discovered in the course of attempts to provide such a solution.

Example I—The problem of the sailors, monkeys and coconuts can be resolved into that of finding the integral solutions of a linear equation in two unknowns.

EXAMPLE I

Let x equal the original number of coconuts.
The first sailor took 1/5 (x − 1) coconuts and left 4/5 (x − 1).
The second took 1/5 [4/5 (x − 1) − 1] and left 4/5 [4/5 (x − 1) − 1].
The fifth sailor thus left $(\frac{4}{5})^5(x-1) - (\frac{4}{5})^4 - (\frac{4}{5})^3 - (\frac{4}{5})^2 - \frac{4}{5}$.
Since this amount was divisible by 5, it can be called 5y.
Thus: $(\frac{4}{5})^5 (x-1) - (\frac{4}{5})^4 - (\frac{4}{5})^3 - (\frac{4}{5})^2 - \frac{4}{5} = 5y$.
Adding terms and clearing of fractions:
$4^5x - 4\cdot 5^5 + 4^6 = 5^6y$.
Since y must be divisible by 4, let y = 4v.

Then: $4^4x - 5^6 + 4^6 = 5^6v$;
Or: $4^4 (x + 4) = 5^6 (1 + 5v)$.
Since $x + 4$ must be divisible by 5^6, let $x + 4 = 5^6w$.
Then: $5v + 1 = 4^4 w$; or: $5v + 1 = 256 w$.
An obvious solution of this equation is $w = 1$, $v = 51$.
Then all solutions for w and v can be found from:
$w = 1 + 5t$, $v = 51 + 256t$.
Hence the formulae for x and y are:
$x = 3121 + 15625t$, $y = 204 + 1024t$, where t is zero or any positive integer.

Thus the smallest number of coconuts there could have been is 3,121, of which each sailor would receive 204 the following morning.

Example II—The problem of finding the years in which Easter Day falls on a given date is that of finding the integral values of N which simultaneously satisfy six linear equations in eleven unknowns.

EXAMPLE II

Let N be the number of the year; and let w be the date of Easter Day in March or w–31 be the date in April.

Then:
$$\begin{aligned} N &= 19x + a \\ N &= 4y + b \\ N &= 7z + c \\ 19a + 15 &= 30u + d \\ 2b + 4c + 6d + 6 &= 7v + e \\ w &= d + e + 22 \end{aligned}$$
where: $a < 19$, $b < 4$, $c < 7$, $d < 30$, $e < 7$.

Example III—The problem of finding three integers such that the sum of the squares of two of them equals the square of the third furnishes a quadratic Diophantine equation.

EXAMPLE III

Consider the equation $x^2 + y^2 = z^2$.
Some integral solutions can be easily guessed:
$x = 3$, $y = 4$, $z = 5$.
$x = 5$, $y = 12$, $z = 13$.

All integral solutions can be found from the following formulae, by allowing m and n to take successively all integral values such that m is greater than n:
$x = m^2 - n^2$, $y = 2\ mn$, $z = m^2 + n^2$.

It is readily seen that the equation is satisfied identically when these formulae are substituted in it.

SEWAGE DISPOSAL DEVELOPMENT IN THE UNITED STATES

By GEORGE L. ROBINSON
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It was not until after the Spanish War, with its dreadful typhoid record, that the problem of the sanitary disposal of sewage was actively taken up by the American engineers, chemists and bacteriologists.

To be sure, with the development of sewer systems in our cities, towns and institutions, some attempt had been made to separate the organic matter from the waste water, but it was done with the thought of preventing unpleasant odors and unsightliness rather than a health protection.

The Massachusetts State Board of Health conducted a series of most valuable experiments at Lawrence and gave out its report as early as 1890. This report was about the first original data from an American source which had real value. These studies were directed along lines of sand filter experiments together with screens rather than any special plan of tank action on the sewage. It was quite natural that under favorable conditions the sand filter beds should be used, as with cheap land and labor and under proper rotation they did produce an effluent of a high degree of purity. However when it became so evident that flies and other insects carried infection from unclean organic matter to food supply and that the intestinal germs infected water supply then the engineers became interested in planning means of purifying the sewage before or during the process of disposal.

It had of course long been known that the oxygen content of the average stream was enough to reduce the or-

ganic matter in sewage so it would not become offensive and would in fact under favorable conditions produce complete ultimate purification. This dilution method has been followed in nearly every city and town in the country. If the streams were large enough and there were no down stream water supplies to be involved the plan did work satisfactorily for many years. It is said that there must be a stream flow of more than three cubic feet per second to dilute and oxidize the sewage production from an average group of one thousand persons. Of course as soon as trade waste, dyes and other chemical by-products reach the sewers the dilution plan fails at once. This is one of the chief causes of stream pollution and the chemicals result in the impairment of the river water to such an extent that the domestic sewage will not break down and properly oxidize.

About the year 1900 the so-called septic tank began to demand the attention of our engineers as a method of breaking down organic matter in sewage by means of the natural fermentation set-up due to the action of anaerobic bacteria. The first claims for the septic tank as a purifying agent were very grossly exaggerated and led to much misunderstanding among the uninformed. This has unfortunately continued to this day.

Among the first experiences with septic tanks on a large scale was the Saratoga Springs Cameron Septic Tank installation which resulted in claims of patent rights and long legal investigation as to their validity. These were heard in the federal courts and while some counts were held in favor of the Cameron Company it finally resulted in an understanding of the subject so that engineers could make up designs of tanks without fear of royalty claims.

The Cameron tank is what is generally understood as a one story settling or septic tank, large enough to hold a day's flow in a state of quiescence, thereby enabling anaerobic bacterial fermentation to develop. The process does liquefy and gasify organic matter to a considerable degree and does produce in time a non-putrescible sludge which forms at the bottom of the tank. The effluent, however, though frequently quite clear, is laden with organic matter in solution and suspension and will quickly become malodorous. It is necessary to provide a secondary treatment either by sand filtration or by spraying over broken stone beds properly underdrained to provide the maximum nitrifying bacteria. Even this filtrate is not always stable and in many cases carries with it intestinal bacteria in such numbers that sterilization by chlorine or some other method is advisable. It is true that in small plants for private estates or institutions the septic tank with proper diffusion of its effluent through the soil has accomplished a sanitary method of solving problems of that kind.

Many manufacturers of boilers and of concrete wash trays have placed stock tanks on the market with stock rules for installing them and this has resulted in much confusion and misunderstanding in the public mind.

About 1906 Dr. Carl Imhoff, while visiting England, noticed the construction and operation of a sewage treatment tank as developed by Travis, at Hampton, England. This was one of the first "two story" tanks and was planned with sloping partitions so the fresh incoming sewage would settle into a separate sludge compartment. Dr. Imhoff then conducted a most careful study in practical operation of the "two story" tank in the Emscher district in Germany. He made modifications in design which had the specific purpose of separating the sewage of the upper compartment from the sedimentation chamber below and keeping out the gas. This was accomplished by pro-

viding a slot in the upper hopper bottom six to twelve inches wide and an overlap of three inches or more measured horizontally. This detail alone distinguishes the Imhoff from the Travis tank. Soon after this period Dr. Imhoff came to the United States and his plans were approved by Mr. Rudolph Hering, the dean of sanitary engineering in this country. From then on this type of tank has been most popular with American engineers. There are many cases, however, where even now it is expedient to use the older one story type together perhaps with a separate digestion tank, or arranged in two or more units so one section may be shut down and allowed to act as a digestor. All types of tanks are subject to modification in their design due to the characteristics of the sewage and its rate of flow.

While much attention was being given to the biolytic tank, yet many engineers were working on screens, separators and other mechanical contrivances which they believed would solve their problems. The patent office is full of drawings of accepted patents on mechanical contraptions most of which have never proved of any great value.

The chemists, too, have taken a large part in the successful development of the art. Much money and thought have been spent on experiments and a number of chemical and electrochemical plants have been built.

The use of lime as a precipitating agent was one of the first and most successful methods used. The process involved the removal of large volumes of sludge which was very hard to dry and difficult of disposal. It had no value as a fertilizer unless mixed with other substances which made the cost too high to be of any great commercial use. The run-off or effluent from these plants was apt to be much discolored and would deposit lime to a noticeable degree in the stream beds. Then also the effluent was so "strong" in chlorine and in lime deposit that it seriously interfered with fish and all other living organisms. The use of electricity was introduced in conjunction with lime as a precipitant and the system was described as an electrolytic process. Experiments showed, however, that the electric current was of little or no value and the cost very high.

At all times bar screens have been used and are of great value in the removal of rags, sticks and other inorganic materials which find their way into the sewers. The fine revolving screens have also been of great help in removing smaller particles. They are particularly helpful in industrial plants, such as tanneries, paper mills and the like, where they can be operated by skilful and interested men. Any screened sewage can of course be treated in tanks just so much more easily. The removal of "screenage" from the screens is accomplished under hand or power operation, depending on the size of the plant and the type of screen in use. This screen product also offers a difficult problem, as it requires dewatering by drying or centrifuging and its ultimate disposal must be by incineration or burial.

The complex nature of sewage treatment caused more and more study along lines leading to rapid oxidation of the sewage water and rapid removal or separation of sludge. The so-called activated sludge process is now quite highly developed, and this type of plant is now approved by engineers of the highest standing. The process as a rule is made up of:

(1) A grit chamber with a coarse screen for the removal of very large objects which may come through the sewers.

(2) An aeration tank in which sludge is activated by aerating sewage for time enough to permit the solid particles to be impregnated with oxidizing bacteria. This is a biochemical process in which the activated sludge is mixed

with the sewage to be treated for a period of from two to four hours.

(3) A sedimentation tank where the effluent from the aeration tank is allowed to remain for half an hour or longer, precipitating its activated sludge. A proper portion of this sludge is then returned to the aeration tank and the excess deposit is withdrawn for drying. The effluent from the sedimentation tank passes off clear and well purified. The sludge as activated is produced by agitating the incoming sewage with air until it has a flocculent appearance. This flow will settle rapidly and contains aerobic bacteria in such numbers that they may be quickly imparted to the sludge of the raw incoming sewage.

(4) A sludge digestor tank or secondary sedimentation chamber is a feature included so that the accumulating sludge removed from the incoming sewage may be properly brought to a condition where gassing stops and it becomes ready for dewatering by drying on beds or with other mechanical means. It is this final product which is used as the base of fertilizer.

A well-designed and operated plant will produce a clear and non-putrescible effluent. There is, however, some division of opinion as to the costs of plant installation and particularly the operating costs.

The most outstanding example of activated sludge plant is at Milwaukee, and much data are available on the results obtained there. The question of the cost of operation and income from dried sludge as a fertilizer has caused much discussion.

There are a number of plants operating in the United States, and the Ward's Island plant for a portion of the City of New York is now under construction. This will treat a sewage flow of 180 million gallons per day and will cost with its collecting works about $30,000,000.

The science is progressing rapidly and it is quite within reason to expect that within another ten years engineering and chemistry will have so improved the plant design that sewage will be treated at much higher rates of flow and at much lower costs both in the original construction and in the operation.

The last thirty-five years just about covers the entire development of sewage treatment in this country. We have made a somewhat slow progress due to the difficulty in arousing public opinion as to the great need of adequate sanitation and the protection of our rivers and lakes.

It is now quite generally understood that the protection of a town's citizens against disease is more important than any other public act its government may make. Sanitary treatment of sewage also helps much in the reduction of cost of living by the increased freedom from disease and offense which our streams when sewage polluted so often caused.

ENVIRONMENT AND THE STUDENT OF HUMAN GEOGRAPHY

By Dr. DERWENT WHITTLESEY

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To the average American, living carefree in his vast continent and careless in his use of words, "international" connotes a kind of cosmopolitanism in which all national bars are thrown down.

That even the genial warmth generated by mutual scientific endeavor is not able to melt away every-day nationalistic attitudes is the discovery every student of human geography makes when he explores the output of his coworkers of other lands. Geographers, it seems, like the subject they profess, are inextricably tied into the environment in which they work. If we cast up the accounts for regional studies alone, or if we consider the whole output of different national (or rather linguistic) groups of geographers, we discover telling contrasts between them.

Students of human geography in large enough numbers to provide a basis for generalization exist in Germany-Austria, France-Belgium, the British Isles, Scandinavia (chiefly Sweden) and the United States.

Of these groups, the Germans have been working longest and have amassed the largest bulk of material, the product of the largest number of minds and pens. German geography has consisted of two related but distinct series of studies: contributions to physical geography and contributions to human geography. Having grown out of geology in Central Europe, physical geography bears the well-disciplined form of the older subject and in effect stands as a branch of it. Human geography, as expounded by Germans, is more miscellaneous in character, and it is almost chaotic in its organization, since there is no agreement as to the order of items to be discussed, nor even as to the topics themselves. In this general field, however, German geography has been given special color by its preoccupation with political conditions. The only periodical devoted wholly to political geography is a German publication, and, among treatises on political geography written since the war, an overwhelming majority have been by Germans. This will cause no surprise to the geographer who recognizes the profundity of the age-long struggle between the Germanies and their neighbors, most of them enemies or potential enemies, who nearly encircle the lands of German language and culture.

British geography emphasizes the physical aspects of the subject, particularly geomorphology, sometimes to the exclusion of human geography. In this it strikingly resembles German work, although it is narrower in scope in that it typically omits biogeography and soil and minimizes climate. Like the Germans also, British geographers have engaged in discussion of political phases of the subject. It would be strange if so preeminent a political power as Great Britain has long been did not manifest this interest. But the number of books and articles published has been only a meager fraction of the German output. British human geography has concerned itself primarily with commercial topics, *i.e.*, with the geography of world trade, to which is articulated a study of commodities produced in various parts of the earth. This is precisely what should be expected from a people whose major

business for 300 years has been the exchanging of products from all parts of the world and provision for their transportation. In this restricted and therefore relatively simple branch of human geography, British work is coherent and systematic, although perhaps perilously close to economics.

The French school of geography, although in its origin the child of history rather than of geology, has come to essential agreement with the British and the Germans as to the independent and significant place which should be accorded to physical geography, or at least to that part of it which concerns landforms. The glory of the French school, however, has been the explanatory description of regions, and geographers of all other countries have found their models for regional geography in the writings of French geographers. Here, again, the trend of thought closely parallels environmental conditions. For many decades France has been relatively free from political stress, either with her immediate neighbors or in her colonial empire; at the same time she has had only moderate commercial interests. As every traveler in France knows, however, France is the land *par excellence* of sharp regional contrasts. In fact, it is strikingly an aggregation of "*pays,*" each of which has its distinctive character stamped upon every aspect of the natural environment and upon every form of human occupance thereof. What more natural than that French geographers should early turn their attention to interpretative description of these regional entities which constantly meet the eye and by their unity seize the attention?

In these three major European language groups have grown up the three initiating schools of geographic thinking in its current manifestation.

To the United States geography first came as a revelation from Great Britain, an event inevitable since books and articles written by British geographers, including text-books, are an open sesame to English-speaking North Americans. Hence the beginnings of human geography in the United States were markedly colored by the commercial thinking dominant in Great Britain. Promptly, however, commercial geography expanded under the genial stimulation of America's enormous unexploited natural resources. It was only a short step from the consideration of trade fed by commodity production, to a study of commodity production facilitated by trade; or, to put it in terms of text-books, American commercial geography rapidly expanded into economic geography.

Coeval with its rooting in British commercial geography was the shoot which geology put forth to make of geomorphology an important part of geography in America. Grafted upon the geographic plant, this branch throve, and with later graftings of climatology, pedology and plant ecology formed a flourishing tree. American geography, however, has not confined itself to the physical and economic phases of the subject because, like everything else in American life, its geography is eclectic. American students have therefore delved into such diverse subjects as political and historical geography, regional geography, conservation of natural resources, cartography and soils. This rambling about the field has kept American geography immature, and at the same time flexible and open to new ideas, including recently some of its own invention.

In Scandinavia geography has likewise been eclectic, but here with the unweighted choice natural to people who share equally, as second languages, all three of those in which human geography first received expression. In view of British and German precedents, physical geography naturally takes its accustomed place. Human geopraphy is by no means shoved into the background, however, and in this field workers lay al-

most equal emphasis upon economic, political and regional study. This seems to be explicable enough in an area of large resources, marked political subdivision and contrasted geographic regions.

If we narrow the discussion from geography in general to that part of the study which by common consent seems to be thought of as its core, namely, regional geography, we reduce the scale of the picture, and at the same time bring our different schools into the same focus.

In treating regional geography we should expect the French to excel, a natural consequence of their early start and assiduous prosecution of regional studies. They have evolved a clear-cut technique, including reconnaissance, field work and well-knit presentation. With a few shining exceptions, the Germans have been left far behind, except in dealing with states as regions. The British likewise have not as yet found themselves in regional geography, except for a small number of workers who have felt the repercussion of thought from French or American shores. The Scandinavians, as might be expected, have seized upon the regional idea with more success. In particular, they have passed their geographic materials through the refining flame of an illuminated cartographic discipline. As they have only lately entered this field, their output is as yet small.

Recently, American geographers have introduced modifications of the regional concept of the Europeans, whether for better or worse time will tell. Europeans, especially the British, have tended to lean heavily upon the superb government maps at their command. Since the best official maps are invariably geomorphic at heart, their users have naturally stressed land-forms. Americans, lacking adequate maps for much of the vast, undeveloped country about them, have been compelled to tackle the field directly as a fresh problem. The construction of maps inherently geographic became for them a primary requisite of field study. The immense labor imposed by this cartographic problem confined studies to diminutive areas, with the result that details have multiplied. Putting these details into the picture has thrown new light on the larger subject of regional geography. The American view-point of regional geography has come to be, ideally, that of a balanced and undivided study of areas (in all their physical and biological aspects) and the human occupance thereof (economic, social and political).

One of the most significant trends in geographic studies is the *rapprochement* between the several schools of thought which has occurred during the last decade. Possibly, after all, there awaits around the corner a cosmopolitan school of human geography.

SCIENCE SERVICE RADIO TALKS

PRESENTED OVER THE COLUMBIA BROADCASTING SYSTEM

THE CONQUEST OF DIPHTHERIA

By Dr. A. W. FREEMAN

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THE conquest of diphtheria, like other important advances of science, has not come suddenly or as the result of a single brilliant achievement. It is the result of more than a century of effort by hundreds of men working in every part of the civilized world. To tell the complete story of its development would be to write the history of science for the past hundred years. Every important advance in science in that time has yielded something of value in the solution of the problem of controlling diphtheria. Without this general advance of science, the disease could never have been controlled.

Diphtheria is an old disease, probably older than any human record. It has prevailed almost all over the world, sometimes in devastating epidemics, sometimes as a constant menace to child life in settled communities. It has been one of the major scourges of childhood. It is always a serious disease. Even when the patient recovers it often damages the heart or kidneys beyond repair. The laryngeal form of the disease, sometimes called membranous croup, is one of the most terrifying diseases to which humans are subject.

In spite of the serious nature of the disease, and of its long and wide-spread prevalence, it was not accurately described and given a name until about 1820, when a French physician, Bretonneau, was able to distinguish it from other affections of the throat and to give it a place as a definite and recognizable disease. This first step was most important of all. Until it had been taken, nothing else of value could be learned about it. Half a century had to elapse after Bretonneau's work before anything more of real importance was accomplished. Science was not yet ready for the solution of the problem. Pasteur had to be born and to grow to maturity before the next step could be taken. The doctrine that living things come only from previously living things had to be established in men's minds. The fact that certain diseases are caused by the entrance into the body and growth there of microscopic living bodies, popularly called "germs," had to be proved and accepted before further fruitful work on diphtheria could be done.

Once this fact was proved, however, it was not long before diphtheria was added to the list of diseases caused by germs. Klebs, a Swiss physician, in 1883, saw under the microscope and described accurately certain very small rods which he took to be the living organisms causing the disease. In the following year, Loeffler, a German, finally settled the question of causation by cultivating these organisms outside the body and proving their connection with the disease. Bacteriologists everywhere confirmed this discovery, and it was soon possible to cultivate the organisms with ease and certainty and to distinguish them from all other known bacteria. The organism was named officially the bacillus of diphtheria, but it soon became known as the Klebs-Loeffler bacillus, in honor of its discoverers.

Once these discoveries became known it was thought that the conquest of diphtheria was at hand. Knowing the

cause of the disease, able to determine by microscopic examination whether or not a given case were diphtheria, certain of the means by which the bacilli left the body, and knowing how easily the bacilli might be destroyed, surely one had reason to believe that the disease might be controlled or even finally eradicated.

Unfortunately, the problem did not turn out to be so simple. Even after all known cases had been isolated and all infectious material destroyed or made harmless, cases of diphtheria continued to appear. Many cases proved on investigation to have had no connection with any previous known case of diphtheria. Many cases occurred far from any previous case. The riddle was soon explained. Diphtheria bacilli are not confined to the throats of people who have diphtheria. Of any thousand healthy people examined, a certain number will almost always be found to harbor diphtheria bacilli in their throats. These persons are able to infect others, though not themselves harmed by the presence of the organism. Why, of two persons similarly exposed to infection, one should become a case and another a carrier could not then be explained. In any event, isolation of the known cases, however perfectly carried out, would not alone control diphtheria. Isolation of all carriers was out of the question as a practicable procedure. Other means of prevention must be devised.

Light began to come from a new quarter. Roux and Yersin, in France in 1888, discovered that the diphtheria bacillus possessed a peculiar property, shared only by one other organism known at that time. When grown under certain conditions in the laboratory, it produces a most powerful toxin or poison. This discovery explained many puzzling things about the effect of the disease on the patient, but it did not immediately help in prevention.

Others, however, had shortly before discovered that when certain plant poisons are injected into animals, beginning with small doses and gradually increasing the amount, in time the animal can take, without injury, an amount many times what would at first have been fatal. Furthermore, the blood of the animals so treated acquires the power to neutralize the poison when mixed with it. The same thing had been found to be true with regard to the venom of reptiles. Protective serums against snake-bite so prepared had already proven their value. Behring, a German scientist, proceeded to experiment with the toxin of diphtheria in the same way. After a time he succeeded in producing a serum which would actually neutralize the toxin. This serum, diphtheria antitoxin, was perfected in 1890. It soon came into general use in the treatment of diphtheria, and its results are almost miraculous. A child infected with diphtheria may be poisoned to the point of death by the toxin produced by the bacilli growing in the throat and absorbed by the blood. When injected promptly with a sufficient amount of antitoxin, improvement is almost immediate and recovery usually follows promptly.

Treatment with antitoxin within a few years reduced the number of deaths per hundred cases from forty or more to less than ten. The total number of deaths, therefore, promptly decreased and has never since approached the old figures. The number of cases, however, remained high, even though it was soon found that if a child had been exposed to diphtheria a small dose of antitoxin would prevent the development of the disease. This protection lasted only a short time, however, and antitoxin could not therefore be used to protect the whole population. More knowledge was needed.

There was a gap of nearly twenty-five

years between the discovery of antitoxin and the next forward step. In that time all known means of preventing diphtheria were used, but the results were disappointing, and health officers everywhere were quite pessimistic as to the possibility of real control.

In 1913, Schick, in Vienna, adapted to diphtheria a method which has been used in the diagnosis of other diseases. Injecting into the skin of the arm a very minute amount of diphtheria toxin, he was able to determine from the reaction, that is, the amount of irritation and reddening which occurred about the site of the injection, whether or not the person possessed resistance to diphtheria. This test was of interest, but its practical value was not immediately evident.

The next and final step, however, was not long delayed. Park and Zingher announced in 1920 that after a long series of experiments they had succeeded in mixing diphtheria toxin with antitoxin in such a way that the mixture, which they called toxin-antitoxin, or familiarly T.A.T., could be injected into human beings without harmful effect, but with the result that the person injected would in a short time develop a resistance to diphtheria sufficient to protect him from infection. So, at long last, the conquest of diphtheria became possible.

Before toxin-antitoxin could be applied practically, however, much more work must needs be done. The laboratory workers had forged the weapons, but before they could be used, means of applying them to field conditions must be devised. The use of the culture for determining the presence of the organisms and of the Schick test for indicating the existence of immunity made the field studies of diphtheria far more accurate and revealing than had previously been possible. Many problems which had previously been incapable of solution were cleared up by these means. From these studies it became clear that diphtheria infection is constantly present in most large communities and that diphtheria bacilli pass readily from person to person. Most city dwellers are repeatedly infected during their lives. Infection early in life or with a large dose of an active culture tends to result in disease. Infection later in life with a small dose of a less active culture not only does not usually produce disease but may actually raise resistance. Most city people have, by repeated exposure to these mild infections, acquired an immunity before they leave school. The fact that diphtheria is more prevalent in childhood is due probably more to the absence of resistance than to the greater infection. Infection is much less common in rural areas than in cities, and resistance comes later if at all. In cities the children of the more crowded areas develop resistance sooner than the children of the well-to-do. Observations such as these clarified the knowledge of the spread of the disease and enabled the new measures of prevention to be applied with efficiency and certainty.

Careful studies had been made as to the ages at which immunization with toxin-antitoxin should be done, the size and frequency of the doses, and the number that must be immunized to secure significant results. Methods of getting people to consent to be immunized and the organization of campaigns for the immunization of school children and of young infants were worked out. These methods have been applied on a large scale only for the past seven or eight years. Hundreds of thousands of persons have now been immunized, and results are beginning to appear. New Haven, Connecticut, a city of 162,000 population, has been three years without a single death from diphtheria. Other cities have done almost as well. Diphtheria death rates have been reduced in almost every state in the Union.

Immunization against diphtheria by toxin-antitoxin has been proved beyond doubt to be safe, effective and capable of general application.

Within the last few years another modification of diphtheria toxin, called "toxoid," was discovered by Ramon. Toxoid is especially suitable for the immunization of infants and children under six and is now generally used instead of toxin-antitoxin for that group.

Using the Schick test to control both the need for and the effect of immunization, almost any individual or any community can now be protected against diphtheria safely and at reasonable cost.

Diphtheria can probably never be eradicated. The fact that it is transmitted by the secretions of the nose and throat and the further fact that the ability of healthy persons to carry the organisms is not affected by immunization would seem to indicate that the organism will continue to exist indefinitely. Protection by immunization is almost everywhere available, however, and the control of diphtheria is a possibility entirely within our reach.

TREE CROPS FOR PAPER MAKING

By Dr. RALPH H. McKEE

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THE talk to-day will present to you a picture of this country's need of more raw material, that is, trees, for paper-making and their possibilities as a farm crop. Most of us take the enormous quantities of books, magazines and newspapers for granted. Paper for them is made from wood which is cut and treated to make paper pulp. I am speaking from New York City. Each week the newspapers of this city use all the paper that can be made from the wood cut on ten thousand acres of pulpwood land. The books and magazines printed here use about as much more each week. If that twenty thousand acres of land is allowed to reforest naturally it will be sixty years before it is again ready to cut. Then it will yield the same amount of wood as before.

It is not generally realized how rapidly the supply of pulpwood in the United States is decreasing. We are now cutting pulpwood about four times as fast as we grow it. The lumber industry also is cutting trees more than twice as fast as we grow them. However, due to special requirements for pulpwood, the reserve is smaller and the shortage will first be severe in the paper industry. Even now more than 50 per cent. of the paper used in the United States is made from foreign-grown pulpwood.

China, Australia, South Africa and the United States are heavy importers of wood. Two thirds of the states of this country are using more wood than they grow and are on the road to forest bankruptcy. Eighty years ago New York and Pennsylvania were the leading wood-producing states. Now they supply only 4 per cent. of what they use. If wood starvation is to be kept at bay we must immediately adopt and rapidly extend the idea of trees as a crop.

Nowhere among the wild trees do we find a combination of all the qualities necessary for such a purpose. The wild trees have been growing as pure species for many centuries. That is to say, they have been inbred and hence deteriorating these thousands of years. It is common knowledge that certain animals and many agricultural crops have been improved, or desired characteristics developed, by cross-breeding, that is, hy-

bridizing. Some familiar examples are the mule, which is a cross between the jackass and the horse; the loganberry, which is a hybrid between the Antwerp red raspberry and the ordinary blackberry. Hybrids, as a rule, grow faster, are freer from disease and, in the case of animals, eat less than either of the parents. Unfortunately they do not breed true, that is, loganberry seeds when planted will grow into raspberry and blackberry plants. It was to be expected that trees might be improved by controlled hybridizing, as had been done with so many smaller plants.

Do ordinary trees grow fast enough to be considered a farm crop? No, they do not. Trees are usually measured at breast height. A spruce eight inches in diameter at that height is about ninety years old. A white pine of the same size is seventy years old and an ordinary aspen or poplar, which is used to make paper for books and magazines, is forty-five to fifty-five years old.

What characteristics will be most desirable in trees to be planted as a farm crop and to be used for paper-making? They must grow rapidly. They must be free from diseases. They must have a large, tall, straight trunk with few branches. They must grow well on poor grades of land without fertilizer or cultivation. They must be propagated by cuttings rather than from seeds. The wood must be light in color and the individual fibers must not be shorter than those of woods now used for paper-making and lumber.

With others I have been working on this problem for a number of years. As subjects I chose trees of the poplar family, because they already had some of the characteristics I wished to develop. For example, cuttings of the hybrid poplar called the Carolina poplar (sometimes incorrectly North Carolina) and known to botanists as *Populus Eugenei* will grow into trees with a diameter of eight inches in twenty instead of fifty years. About the only requirements for rapid growth of this variety are sunshine and moderate rainfall in each of the months of May, June, July and August. The slash pine which grows in the South will do fully as well as the Carolina poplar. However, it could not be used to advantage in the whole country, as it does not grow well north of Georgia, whereas the poplar is at home North and South.

During the past several years we have hybridized selected poplars and grown some fifteen thousand seedlings, from which we kept the fastest growing individuals. We now have a number of new hybrids that grow more rapidly than any variety of tree now used for pulpwood or lumber. We have every reason to expect that the new hybrids will give us an eight-inch tree in ten years—a fifth the growing time of the ordinary poplar, or half the growing time of the Carolina poplar. The quality of the wood apparently is not adversely affected by the rapid growth. Indeed, the fiber tests even better than that of wild poplar.

The parent wild poplar trees grow less than two feet in height a year. The better varieties of the new hybrid poplars add between five and six feet in height a year. In the particularly favorable season of 1931, I had four especially vigorous trees, each of which grew nine feet six inches in the growing months of May through August. However, that is better growth than is to be expected in a normal year. Under the present patent law, new hybrid plants can be protected by patent. The law applies to trees as well as to smaller plants, and so patent applications have been filed to cover the new hybrid trees.

In Italy and France many acres are planted with Carolina poplars for the production of lumber. The profit of such plantations compares favorably with similar acreages planted with wheat or corn and the soil need not be

nearly so rich. In these days of surplus farm crops farmers should plant their less productive lands, if well-watered, with trees.

Timber has a diversified market, both as lumber and as pulpwood. It has the further advantage that tree crops can be left growing until wanted. Instead of spoiling like a forage crop, they increase in size and value. It is not necessary to market the wood when the price is low. We have every reason to expect greater returns per acre per year from trees as a farm crop than from wheat or corn. Most states now free reforested areas from taxes until the year the trees are cut. This tax exemption for the period of growth is a great help and should be an inducement to farmers to grow trees.

My suggestion is to plant such trees as Carolina poplars or slash pine now. They will make a profitable crop in most localities, even though the farmer has to wait a number of years before he cuts them. The experience gained in planting and handling these trees will permit him to embark with every assurance of success on cultivation of the new and still faster growing hybrid poplars when their cuttings become generally available a few years hence.

Can farmers grow crops of trees? They can, indeed, and profitably.

THE PROTECTION OF OUR NATIVE FLOWERS

By P. L. RICKER

PRESIDENT, WILD FLOWER PRESERVATION SOCIETY

FEW people who have not seen the wild riot of color still to be found on some of our Western plains and mountain meadows can form any idea of the wealth of flowers that must have greeted the early settlers of this country. The places in the East where such displays can still be found are very few, compared with the West, and in all sections of the country they are becoming fewer each succeeding year. The present scarcity of wild flowers is due largely to three causes and over the first two of these little or no control is possible. These causes are: (1) the clearing of land for agricultural purposes; (2) real estate developments for small homes; and (3) fire.

In the early days the settlers found it necessary to cut down trees and clear the land to establish small farms. These have been increased in size by further cutting, and in the more densely populated districts the few remaining woodlands and fields are being rapidly destroyed by real estate companies for small home developments. In many such cases all trees are cut down, hills are leveled and the soil dumped into the hollows to secure level ground. The resulting homes are left exposed to the scorching sun, with few or no trees to shade and make them more attractive. The once rich surface soil, containing humus from the decay of leaves for countless years, is usually buried and the resulting subsoil surface is little suited to the use of the home seeker, without years of patient work of restoring fertility.

Before the advent of man in this country, forest fires were set by lightning as they still are occasionally. The Indians first set fires to clear the land to cultivate maize and then to establish hunting grounds for the buffalo. That our Western plains states once bore an abundant forest is attested to by the finding of buried trunks of fossil trees. From the early burning of land for

clearing purposes there has persisted a tradition that the burning over of pasture and hay land every fall or spring is a necessity in order to liberate in the ash the fertilizing elements, but what actually happens is that the humus of the soil, formed by the decay of vegetation and the soil bacteria in this humus which do the actual freeing of the fertilizing elements, are destroyed by such fires and the ground further impoverished.

In some parts of the South, this burning has been so consistently practiced that both the roots and seeds of the attractive wild flowers have been destroyed to such an extent that the flowers are rarely seen. In other parts of the country the land has been so completely taken up for farm purposes that I was informed by a Pennsylvania farm-raised girl applicant for coloring lantern slides of flowers that she did not think there were any wild flowers in Pennsylvania.

The thoughtless throwing aside of cigarette and cigar stubs and pipe cleanings, the leaving of unquenched camp fires in the woods by hikers, picnickers, sportsmen and campers, causes hundreds of serious forest fires every year, destroying the very flowers, trees and game that brought them to the woods, and causing more landowners to bar such use of their woods each year. Be sure your ashes and stubs are ground under foot until out and your camp fires wet down and buried, if you want to continue to use these woods.

No species of wild flower is found in all parts of the country, and a species that is very rare in one part of the country may become very abundant in another part not more than two hundred to three hundred miles away. This is well shown in the rapidly increasing abundance of the mountain laurel from Maine to the mountains of North Carolina, where it makes its most wonderful floral display. It even happens that a flower that is abundant in the northern part of a single state is rare in the southern part or *vice versa*, and the same may be true between adjoining counties or from the top to the bottom of a single mountain. The problem of deciding just what wild flowers need protection and what ones do not is therefore decidedly complicated.

A safe rule to follow is that no attractive wild flower, except the well-known weedy ones, should be picked for bouquets, unless there are at least one or two hundred of them, and then pick not more than one out of ten flowers. The spring flowers that grow in the woods are also the ones most in need of protection. A much larger proportion of the summer and fall flowers grow in open fields and along roadsides, have more aggressive root and seed habits, and as a general rule, where abundant, may be picked freely with little danger of extermination.

In many of our largest cities there are countless thousands of children who have never seen any of our native wild flowers, and in the smaller cities, where there may occasionally be a vacant lot, their vision has been limited to the flowers of such weedy, wind-borne seeds as the dandelion, thistle, wild lettuce, ironweed, chicory, goldenrod and jo-pye-weed. Most of them have heard of that elusive fragrant beauty—the trailing arbutus—but few children, except those living in the country, and few adults, unless country-born, have ever seen it. It is extremely difficult to grow from roots, even in acid soil, but it grows from seed much more readily.

Even more elusive is the beautiful fairy slipper orchid Calypso, named for the nymph who tried to "vamp" Ulysses, and found in the cooler bogs of both continents. Recently a Northern lady of nearly threescore years, who has traveled extensively, came to my office for help in finding a place to see

it, and stated that she and her mother, a college professor of botany, who had recently died at advanced years, had sought it in vain all their lives. Most other orchids, while not so rare, should be protected. Few can be grown from seed or roots under ordinary garden conditions. Another nearly as elusive flower is the fringed gentian, which is rarely found, except in cool, damp meadows of the East and mountain meadows of the West. It can not be cultivated in garden soils without providing its native conditions, and then only from seed in the case of the Eastern species, which is a biennial.

In some of the Middle Western states the railroad right-of-way and the roadsides furnish about the only view that the average city-dweller of the region can obtain of wild flowers, and some of these displays are often very attractive. They, however, often include bad weeds, to which the farmer objects, and the railroad finds them a serious fire menace; so that many of these sources are now annually cut or burned one or more times every year.

A few railroads at higher elevations and with less weedy subjects have used the color display in their advertisements to induce nature lovers to use their line, and one railroad has one of its dining cars named and service and menu decorated with a blue columbine motif, and a request to "Hold sacred that which is beautiful." This attractive flower is the state flower of Colorado and has been ruthlessly destroyed in many places by too much picking, but in the more inaccessible places it is still found in abundance. In California the native poppy, which is the glory of the fields, is rapidly decreasing in abundance. In the Southwest many species of cactus, which were thought to be proof against extermination, are now being commercialized to such an extent, for gardens, confections and recently the juice as a reputed preventive of scale in boilers, that their existence in many localities is seriously threatened. Very few plants have as attractive flowers as the cactus, and a tree cactus species is the state flower of Arizona.

Laws for the protection of some of the rarer wild flowers have been passed by twenty-two states, but there is very little enforcement in any of them. If enforcement is really desired, the common law covering trespass and theft is sufficient for making prosecutions without unnecessarily encumbering the statutes with further laws of doubtful value. Education in the schools is one of the most effective methods of protecting the flowers still remaining, supplemented by newspaper and magazine articles, motion pictures and colored lantern slides with lectures.

Where they can be given adequate protection, permanent wild flower sanctuaries should be established, but without protection, fires, picking, digging up plants for private gardens, and picnic refuse will soon make them look as bad as the average city dumping grounds. It is the desire of the Wild Flower Preservation Society to obtain land and funds for establishing such protected sanctuaries where with expert supervision many of the flowers can be sufficiently increased in abundance to enable distribution of some of the rarer species to protected areas, where they are adapted but are at present rare or little known. Circulars on the need for wild flower protection, and listing as well many of those that may be picked freely, with directions for cultivation and list of seeds available, may be obtained free by addressing the Wild Flower Preservation Society, Washington, D. C.

CHEMICALS MAKE FIRE-FIGHTING DANGEROUS

By LIONEL K. ARNOLD

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WE are living to-day in a chemical age. No where is this more apparent than in fire-fighting. Not so many years ago fire-fighting was merely what the name suggests, fighting fire. If you could get enough water on the blaze it was out and that was about all there was to it. Of course, there were always the hazards of falling floors and walls and the danger of being overcome by smoke but these dangers seem trivial compared to those introduced by the modern wide-spread use of chemicals. One of the peculiar hazards introduced by the chemicals is that of uncertainty as to what to expect. The introduction of new chemicals into common use forces the fireman to always be informed upon new industrial chemical uses in order to keep abreast of the times.

Various hazardous gases have come into such common use as to present definite hazards to firemen. These gases may be poisonous, explosive, or merely inert. They are commonly shipped and used in heavy steel cylinders ranging in size from the so-called "lecture bottles" 14 inches long by 2 inches in diameter to the one-ton chlorine cylinders which are 80 inches long by 30 inches in diameter. These cylinders (Fig. 1) are strongly constructed and fitted with carefully inspected valves so that the hazards arising from normal use are not great. The high temperatures occurring in fires cause a tremendous increase in pressure which, if not relieved, may burst the cylinder. To guard against this the cylinders are equipped with fusible safety plugs (Fig. 2) which melt at 150° F. allowing the gas to escape. Unfortunately, the temperature is frequently so great that the increase in pressure can not be prevented by the use of such a small opening and the cylinder bursts with explosive violence. Whether the

FIG. 1. VARIOUS TYPES OF GAS CYLINDERS.

LEFT TO RIGHT: ACETYLENE, CARBON DIOXIDE, OXYGEN (SIMILAR TO CYLINDERS USED FOR AMMONIA AND CHLORINE), OXYGEN WITH PROTECTING CAP USED IN SHIPPING, ACETYLENE.

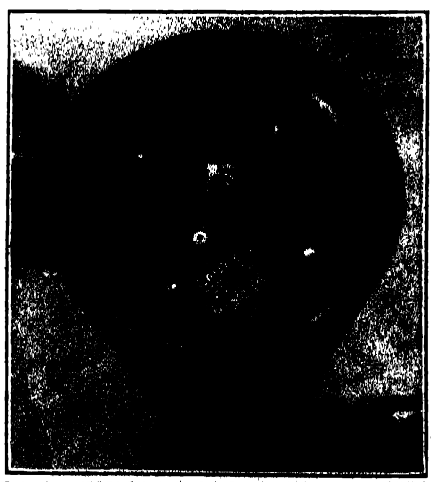


FIG. 2. FUSIBLE PLUGS IN AN ACETYLENE CYLINDER.

THE FUSIBLE PLUGS ON THE OXYGEN AND SIMILAR CYLINDERS ARE ON THE SIDE OF THE VALVE OPPOSITE THE DISCHARGE OPENING.

cylinder bursts or the gas merely escapes through the safety opening the hazards of the specific gas are introduced into the fire unless the cylinders can be removed before the fusible plug melts. Frequently after a fire has been extinguished there will be present gas cylinders which are leaking from the safety openings. Sometimes it is possible to plug these openings with a wooden plug which when wetted swells to a tight fit. Cylinders plugged in this way should be hauled to a suitable dumping place and the gas allowed to escape where it will cause no injury. If a poisonous gas, it should be handled with great care only by men equipped with gas masks. Care should be taken that no hazard to life is caused in the release of the gas. For example, if chlorine is released along a stream, being heavier than air, it may follow along the valleys filling them far downstream with concentrations sufficient to be serious to man or beast.

Some of the poisonous gases available in cylinders are chlorine, ammonia, sulphur dioxide, hydrogen sulphide, hydrogen cyanide, phosgene, methyl chloride and carbon dioxide. Cylinders of chlorine may be encountered in paper mills, water-works and swimming pools. Sulphur dioxide is used in mechanical refrigerators, in fumigation, and as a bleaching agent. Much of it used in factories is produced by burning sulphur although considerable is shipped in cylinders.

Ammonia is commonly used in large mechanical refrigeration installations and cold storage rooms. Hydrogen sulphide is commonly made as used although some of it is shipped in cylinders. Hydrogen cyanide is used as an insecticide and in fumigating buildings. Phosgene is used mainly in dye works. Methyl chloride is used in household mechanical refrigerators. Carbon dioxide is ordinarily not considered dangerous but is poisonous when present in sufficient quantities. It is used in refrigerating equipment, soda fountains, and bottling works.

Flammable gases which introduce explosion hazard into the fire include acetylene, hydrogen, ethlene, ethyl chloride, and various compressed cooking gases. Acetylene is used mainly for welding (Fig. 3) and is commonly found

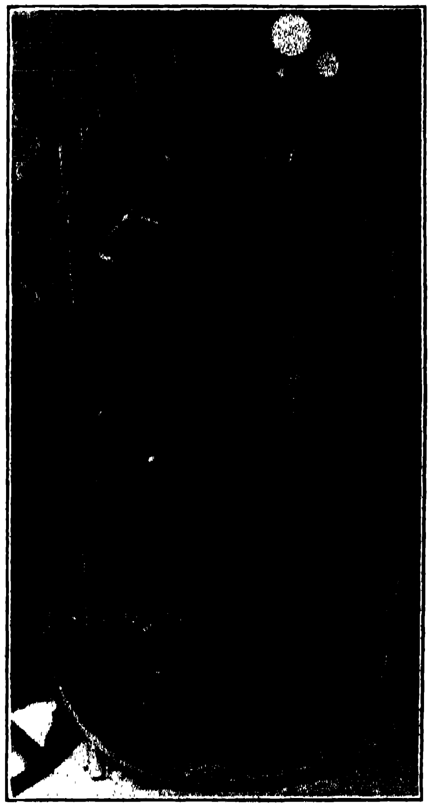


FIG. 3. CYLINDERS OF ACETYLENE AND OXYGEN USED FOR WELDING.

in machine shops, metal working factories, garages, and all other places where welding is done. Hydrogen is used for welding, hardening vegetable oils, and filling balloons. Ethylene is used in welding, in medicine, and for ripening citrus fruits. Ethyl chloride is used in medicine, dentistry, as a solvent, and in household electric refrigerators.

Various other gases such as nitrogen

and helium which present no poison or explosion hazards are available in cylinders and present the danger of possible explosion because of rapid heating. Oxygen, which is used in welding, will increase the combustion rate of a fire.

Gases are only a few of the chemicals in common use. The liquid acids such as sulphuric, nitric, hydrochloric (muriatic), and acetic acids are commonly shipped and stored in glass bottles and carboys. The carboys are glass bottles (Fig. 4) holding 12 gallons and enclosed

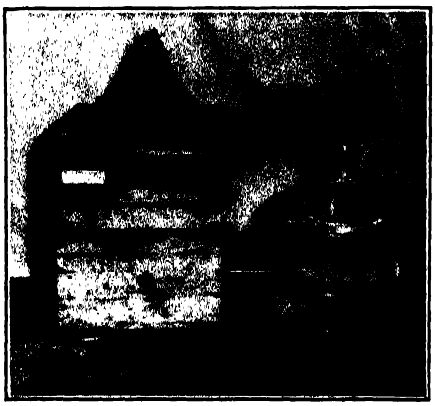


FIG. 4. CARBOYS OF ACID.
LEFT: COMPLETE CARBOY AS SHIPPED. RIGHT GLASS BOTTLE WHICH HOLDS THE ACID.

in individual wooden boxes. Some acids are shipped in special tank cars. There is always danger that the glass containers will be broken by heat, falling débris, or a stream of water from the fire hose. All of these acids are corrosive to the skin. The application of water to strong sulphuric acid may result in spattering the acid over considerable space. The fumes of both hot sulphuric and hydrochloric acid are irritating and poisonous but nitric acid is particularly dangerous since in contact with organic matter and metals evolves the very poisonous nitrous oxide fumes. Dilution with large amounts of water prevents the formation of these gases. These acids are common in drug warehouses and stores, laboratories, and chemical plants.

Various oils and other flammable liquids present hazards which are widespread because of the large amounts sold for automobile use. Small oil fires are readily handled with carbon tetrachloride or foam extinguishers. Large oil fires must be handled according to the individual conditions involved. Special fire-fighting equipment for applying steam, foam, or carbon dioxide to oil storage tanks for fighting refinery fires is largely used. The flammability and explosibility of oils depend upon the volatility of the oil itself and the amount of oxygen present. This means that the explosion hazard varies not only with the oil, but the conditions to which it is subjected. At either ordinary or elevated temperatures the concentration of gasoline vapor in storage tanks above the liquid is too great to be explosive. If the tank is cooled by applying water the concentration may be lowered within the explosive range of between 1 and 6 per cent. The vapor above kerosene and lubricating oils, on the other hand, is usually too lean to be explosive until heated so that it is good fire-fighting practice to cool these tanks with water.

Other hazards of this type are furfurol with about the same volatility as kerosene, benzol similar to gasoline, alcohol about intermediate between gasoline and kerosene and turpentine similar to alcohol.

Solid oxidizing materials such as chlorates, perchlorates, nitrates, and peroxides increase the rapidity of combustion. In contact with organic matter they may cause explosions. Except for the peroxides which are explosive in contact with water these materials may be safely wet down. Water must be kept away from certain metals such as potassium, sodium and magnesium which liberate hydrogen from it, increasing the fire hazard. In the case of the potassium

and sodium the hydrogen bursts into fire spontaneously, spattering the metal over considerable distance. Phosphorus, picric acid and sulphur, on the contrary, should be kept wet down with water.

Various nitrocellulose products such as photo films, moving picture films, x-ray films, and celluloid products on burning evolve very poisonous nitrous oxide fumes. The hazard from this source is possible in such places as moving picture film storehouses, photo supply stores, hospitals, and stores selling celluloid products. The large amounts of celluloid novelties sold in 5 and 10 cent stores gives them a possible hazard rather unexpected in such a type of business. Since the nitrocellulose contains oxygen for its own combustion, fires in it can not be extinguished by merely cutting off the air supply but are most effectively fought by cooling below the ignition temperature by drenching with water.

Even this brief survey which of necessity does not include all hazardous chemicals indicates some of the dangers to the fireman in fighting modern fires. He may be gassed with ammonia in an ice plant, cold storage, grocery, or meat market fire. Even the small electrically operated refrigerators in homes may contain enough poisonous gas to be dangerous. Welding gases in garages and shops offer explosion hazards. Several hospital fires have occurred in which both inmates and firemen have been killed by nitrous oxide fumes from x-ray films. A stream of water may knock enough poisonous chemicals such as bromine or some of the acids from the shelves of a laboratory storeroom (Fig. 5) in a high school or college to be dangerous to all in the room.

FIG. 5. A TYPICAL GROUP OF HAZARDOUS CHEMICALS IN A LABORATORY.

Certain safeguards are available. If the concentration of poison gases is low, a gas mask of the canister type will give protection against poisonous gases and fumes. But in air containing a deficiency of oxygen or more than 4 or 5 per cent. poison gases, dependence can be placed only upon an oxygen helmet. For the most part, the fireman must depend upon his knowledge of the chemicals likely to be involved. For this reason the progressive firemen are studying the chemical hazards which occur. They are familiarizing themselves with the location of all of these hazards in their territory before the fires actually occur.

GRAHAM LUSK

THE PROGRESS OF SCIENCE

GRAHAM LUSK

THROUGH the untimely death of Professor Graham Lusk, on July 18, 1932, at the age of 66 years, physiology has lost one of its distinguished devotees, and the science of nutrition, in particular, one of its foremost promoters in America. Born in New England, the descendant of a line of well-known ancestors, he received his collegiate education at the School of Mines, with a degree from Columbia University in 1887. With a chemical training thus secured, he proceeded to Munich to embark upon the study of physiology under the guidance of an eminent master of the science of nutrition, Carl v. Voit. Any one who has heard Lusk discuss his experiences during the four years spent abroad at that time could not fail to realize the profound influence that life and work in the German university exerted upon him and his subsequent career. In after years his publications, his addresses and his intimate conversations abounded in interesting references to the leadership and tuition of v. Voit. Few pupils have retained such supreme devotion to an inspiring teacher.

Equipped with the degree of doctor of philosophy from the University of Munich in 1891, after an examination conducted by the eminent German chemist, A. v. Baeyer, Lusk at the age of twenty-five was placed in charge of physiology at the Yale Medical School in New Haven. At the outset the "department" consisted of one room in an old building. There he began his independent scientific researches; notably, the well-known studies on the action of phlorhizin, affording permanent contributions to our knowledge of the metabolism of carbohydrates in the body.

In 1898, after seven fruitful years, during which he never had a paid assistant, Lusk became associated with the University and Bellevue Medical College, New York City. He was proud of his new affiliation with an institution where his father, Dr. William T. Lusk, an obstetrician of international reputation, had earlier served as dean. After the opening of the Cornell University Medical College in New York City, Graham Lusk became professor of physiology there in 1909, voluntarily retiring from this post at the end of the present academic year in June. Though apparently still vigorous in both body and mind, he had planned to divorce himself almost completely from the active pursuit of his professional interests. In reply to the protests of the writer, he made the characteristic remark, only a few months ago: "I can well recall the words of criticism that I often uttered somewhat violently, when I was in my thirties and forties, about persons whom I regarded as antiquated and reactionary medical teachers of my present age. I shall therefore endeavor to avert a similar fate for myself at the hands of the present-day youngsters, by retiring."

This is not the place for detailed reference to Lusk's scientific contributions to our knowledge of physiology. He was a pioneer in the study of animal calorimetry in this country. The small calorimeter in his laboratory was a research apparatus that has furnished many outstanding facts regarding the fate of the foodstuffs and their derivatives in the living organism. The problems of diabetes, of the specific dynamic action of the nutrients, of the rôle of the amino acids—these and many other aspects of metabolism were attacked with unfailing energy, painstaking technique and unsparing criticism. Lusk's "Elements of the Science of Nutrition," which passed through several editions and was translated into at least one foreign language, has been a standard

text and reference book for many years in all parts of the civilized world. He contributed chapters to various textbooks, including the early "American Textbook of Physiology" and Barker's "Metabolism." The latter contains Lusk's delightful essay on the history of the subject. The "Fundamental Basis of Nutrition," a small volume devoted to problems of diet in wartime, was widely read.

Dr. Lusk was frequently called upon to speak before large audiences. These addresses were prepared with great care. Some of them, particularly in the earlier years of the century, dealt with the reform of medical education and the promotion of research. They were fearless expressions of opinion, usually delivered with the ardent enthusiasm of a crusader. Lusk's intense interest in the promotion of better opportunities for scientific work, the diffusion of scientific knowledge and academic freedom and opportunity in this country and particularly in New York, was unquestionably productive of much good. He was active in the organization of the Harvey Society in New York City and the Society for Experimental Biology and Medicine, likewise originally a local society. To one of his friends he has written: "In New Haven my life was one of peace for seven years. In New York it became one of fierce combat—largely against my father's old friends. But two of these old friends successively stood behind me, Dr. E. G. Janeway and Dr. William M. Polk." The intervening years have indeed witnessed profound changes in the development of the medical sciences in the metropolis.

To Lusk the teaching of students was an engrossing task until the end of his life. There were always a number of advanced workers, including foreign pupils, in his laboratory. The mental discipline was rigorous; his delight in their successes was unfeigned. Among the research students were Howland, Murlin, Ringer, Williams, Wiggers, Edwards, Cattell, Anderson, Gephart, Wilson, Csonka, Chambers, Rapport, Deuel and others whose names have become familiar in physiological literature.

During the world war, Lusk became a helpful adviser to the U. S. Food Administration. In company with R. H. Chittenden he was sent abroad as an American member of the important Interallied Scientific Food Commission, which included T. B. Wood and Starling of England, Gley and Langlois of France, and Bottazzi of Italy.

Early in the history of the Russell Sage Institute of Pathology, Lusk became a member of the board of directors and in turn its scientific director until his death. He was instrumental, notably through the cooperation of Dr. E. F. DuBois, the medical director, in initiating a long series of investigations on clinical calorimetry with the aid of the large respiration calorimeter, built and maintained in Bellevue Hospital, New York City. There many of our fundamental conceptions of metabolism in disease have been established.

Academic honors came to Lusk in liberal measure from many parts of the world. He was an honorary doctor of medicine of the University of Munich; doctor of laws of the University of Glasgow; fellow of the Royal Society of London, and so forth.

Few persons exhibit the singular personal charm that was a much admired characteristic of Graham Lusk. To his friends—and they were many—he was truly a lovable individual. He was a genial host. Many scientists will recall the unbounded hospitality that Lusk delighted to extend upon every appropriate occasion to his colleagues at his home or his club. Thus he enjoyed the privilege of entertaining the foreign members of the International Physiological Congress at his summer home on Long Island in 1929.

A unique spirit of friendliness, combined with dignity and uprightness, suffused his life. He had a fine appreciation of his colleagues; but he hated sham and never hesitated to expose it. Only a few months ago, at the Philadelphia meetings of the Federation of Biological Societies, Lusk made an address that was in truth a valedictory, preceding his retirement from academic life. He attacked with all the vigor at his command certain tendencies in education that he regarded as vicious; then he fervently defended one of his own scientific views that has latterly been questioned; and finally, in a kindly endeavor and in a spirit of calm retrospect, he recalled some of the pleasantries of an exchange of correspondence with his colleagues—a final tribute of an appreciative scientist to the cheerful, human side of life.

LAFAYETTE B. MENDEL

THE PEARL OYSTER RESOURCES IN THE PACIFIC

IN 1930 the United States Bureau of Fisheries, in cooperation with the Navy Department, who assigned the minesweeper, *Whippoorwill,* to assist in the work, sent an expedition to study the pearl oyster beds at the Pearl and Hermes Reef off the end of the Hawaiian Archipelago.

The expedition was in charge of Dr. Paul S. Galtstoff, who, for some time, has been in charge of the extensive oyster investigations of the United States Government. The official report of the expedition will be completed in August.

The Pearl and Hermes Reef is a small atoll situated about 76 miles east from Midway Island and 1,100 miles west of Honolulu. Since the discovery of Pearl and Hermes Reef in 1822 by two British whaleships which, on the night of April 26, were wrecked within ten miles of each other, but a few persons visited this place. In 1858 Captain Brooks, cruising on the U. S. S. *Gambia,* explored the atoll. In 1867 it was surveyed by U. S. S. *Lackawanna.* Then it was visited in 1912 by a German engineer, Elschner, engaged in a study of phosphate rocks of the Pacific; and in 1923 by Dr. Wetmore, of the National Museum, in charge of the *Tanager* expedition. In 1927 extensive pearl oyster beds, discovered on the reefs of the lagoon, attracted fishermen and pearl oyster divers from Honolulu and Japan. With the exception of one case, small fishing boats (sampans) were either lost at sea or, having failed to reach their destination, were forced to return home. Intensive shelling operations were carried on, however, by one company who dispatched a schooner to Pearl and Hermes and on one of the islands erected several buildings which served as comfortable headquarters for our expedition.

The lagoon is about eighteen miles long and twelve miles wide. It is partially surrounded by a narrow strip of coral reefs which embrace it on the east, south and southwest, leaving the northern and northwestern sides unprotected. A series of islands, most of them merely sand bars, extends from the northwestern corner along the eastern and southern sides of the lagoon. The lagoon itself comprises a maze of small reefs and channels, with the depth of water varying from a few inches to 104 feet. The reefs growing inside the lagoon are made up by finger-like corals. The predominant forms, primarily responsible for the building up and maintenance of the encircling reef, belong to the species of Porites and Pocillopora, the colonies of which are strongly reinforced by the luxuriant growth of numerous nullipores. The rôle of these algae in building up reefs is probably equal, if not superior, to that of the corals.

Between the coral reefs the bottom of the lagoon is covered with shifting sand which, at the depth of about fifty feet, and below, is replaced by soft and sticky coral mud. Configuration, depth and

DR. CARL KOLLER RECEIVING A MEDAL

FROM THE NEW YORK ACADEMY OF MEDICINE IN RECOGNITION OF HIS RESEARCHES WHICH RESULTED IN THE DISCOVERY OF THE ANESTHETIC PROPERTIES OF COCAINE AND INAUGURATED THE ERA OF LOCAL ANESTHESIA. THE PRESENTATION OF THIS FIRST ACADEMY MEDAL IS BEING MADE BY ITS PRESIDENT, DR. JOHN H. HARTWELL.

distribution of reefs, sand and mud reflect the prevailing physical conditions and can be easily understood if one realizes that the present features of Pearl and Hermes, which in many respects can be regarded as a typical atoll, are determined both by the constructive forces of the reef-builders and destructive action of waves, breakers, wind, rain and various organisms, contrary to Darwin's well-known conception of atoll formation, which implies a gradual subsidence of the foundation and filling up of the lagoon with sediments, there are numerous indications that the material forming the floor of the lagoon is constantly being washed away and deposited at a greater depth outside the encircling reef. A comparison between the charts prepared in 1867 and in 1930 show noticeable increase in the area of the lagoon, especially at its southeastern corner. An important rôle in the destruction of coarse material of the lagoon floor and its reduction into fine mud is attributable to a large black bêche-de-mer, an organism measuring over a foot in length and weighing several pounds. Millions of these sluggish animals are found everywhere on the bottom, being especially conspicuous on the white background of the sandy shoals. Experiments with related forms, made in the atolls of the Indian Ocean and in Japan, show that the intestines of the bêche-de-mer of that size may contain as much as 88 grams of sand and that about half of that amount is ingested daily and passed through the intestinal tract.

Biological observations of the expedition consisted in making soundings. taking samples of bottom and water, temperature readings (top and bottom), determination of the alkalinity of the water, of its transparency and of its food content. For the examination of pearl oyster beds three divers were employed. They were directed to swim and dive for periods of time varying from half to one and a half hours. Because of the irregular distribution of pearl oyster beds the total number of the present oyster population of the lagoon could not be determined. However, from the data obtained during the investigation it is possible to determine the relative abundance of oysters, *i.e.*, the number of oysters found by the average diver during a given period of time. Biological observations just described were carried out at seventy-five stations uniformly distributed over the whole area of the lagoon. From a preliminary analysis of the data the following conclusions can be drawn:

The pearl oysters grow at the depth from 10 to 47 feet, attached almost exclusively to live corals. The average weight of the adult oyster is about two pounds; the maximum weight is seven pounds, but at present the oysters weighing over three pounds are rather scarce. The largest one obtained in 1928 weighed fifteen pounds. All the oyster reefs examined in the course of the investigation show obvious signs of depletion. The scarcity of the oysters is evidenced by the fact that on the best reef three divers were able to find in one hour only twenty-one oysters; on most of the reefs only three or four oysters were found during the same length of time.

One-year-old oysters were almost entirely absent. This fact indicates that either oysters failed to spawn and set in 1929 or that the 1930 crop was destroyed by fishermen. Because small oysters have a tendency to attach themselves to the shells of the adult ones, the second explanation seems to be very probable. Pearl oysters spawn and set in Pearl and Hermes lagoon in July and August. Two factors essential for successful spawning are high temperature of the water (27° C.) and an abundance of adult oysters on the reef. When the number of adult oysters on the reef is reduced to a certain low limit the oysters fail to spawn and their propagation ceases. The evidence supporting this statement is found by isolating single in-

A LONG-RANGE PHOTOGRAPH OF MT. SHASTA

TAKEN FROM AN AIRPLANE WHICH WAS 331.2 MILES SOUTH OF THIS POINT. THE PHOTOGRAPH WAS TAKEN ON AN INFRA-RED SENSITIVE PLATE BY CAPTAIN ALBERT W. STEVENS, OF THE U. S. ARMY AIR CORPS.

dividuals taken from badly depleted reefs, and those from the reefs that were not so badly overfished. In the former case, the spat was sparse or absent, while in the latter case it was abundant.

Pearls are procured mainly from the Sulu Seas, off the coast of Australia, Central America, Ceylon, Japan and some of the south Pacific islands. The ancient fisheries of Ceylon (Taprobane) are situated in the Gulf of Manaar, the fishing banks lying from six to eight miles off the western shore, a little to the south of the island of Manaar. The Tinnevelly fishery is on the Madras side of the strait, near Tuticorin. These Indian fishing grounds are under the control of government inspectors, who regulate the fisheries. The oysters yield the best pearls at about four years of age. Fishing generally commences about the middle of March, and lasts from four to six weeks, according to the season. The boats are grouped in fleets of sixty to seventy and usually start at midnight in order to reach the oyster-banks at sunrise.

Each boat generally carries ten divers. On reaching the bank a signal gun is fired and the diving begins. A stone weighing about forty pounds is attached to the cord by which the diver is let down. They work in pairs, and one man dives while the other watches the signal cord, drawing up the sink-stone first, then the haul of oysters, and finally the diver. On an average, the diver remains under water from fifty to eighty seconds, although there have been instances where some have remained as long as six minutes. The diver makes skillful use of his toes while under water; and to arm himself against sharks he carries iron spikes. The genuine Indian diver never goes down without the ritual of the shark-charmers.

Pearl-fishing is actively prosecuted along the western coast of Central America, especially in the Gulf of California, and to a less extent around the Pearl Islands in the Bay of Panama. Fishing grounds are in water about forty feet deep, and the season lasts for four months. An ordinary fishing party expects to get about three tons of shell per day, and it is estimated that one shell in a thousand contains a pearl. Dr. Galtsoff estimated that in the Hawaiian grounds at least ten per cent. of the shells carried pearls. He returned with 150 shells, fifty of which carried pearls of some size.

As is well-known, when a pearl oyster is attacked by a boring parasite the mollusk protects itself by depositing nacreous matter at the point of invasion, thus forming a hollow body of irregular shape called a "blister" pearl. Hollow, warty pearls are sometimes termed in trade *coq-de-perles* and all irregular-shaped pearls are known as *perles baroques*. A pearl of the best quality should be of delicate texture, free from speck or flaw, and of clear, almost translucent white color, with a subdued sheen.

Pearl oysters, of Pearl and Hermes Reef, produce valuable shells (mother-of-pearl) and bear large numbers of pearls. They represent valuable natural resource, which shows signs of depletion caused by over-fishing. It is estimated that since 1927, when pearl beds were discovered, more than 100 tons of shells (about 106,000 oysters) have been taken from the reef. It was, therefore, thought advisable to close pearl-oyster fishing and to forbid taking of pearl oysters in Pearl and Hermes Reef until the beds have been restored by natural propagation of the oysters. Several hundred pearl oysters were taken to Kaneohe Bay and planted on the reefs (near Coconut Island or elsewhere), where conditions are suitable for their growth and propagation.

When the pearl beds at Pearl and Hermes Reef have been restored they could be opened for fishing under government supervision, with such restrictions as it would be necessary to impose, in order to protect them from depletion and destruction.

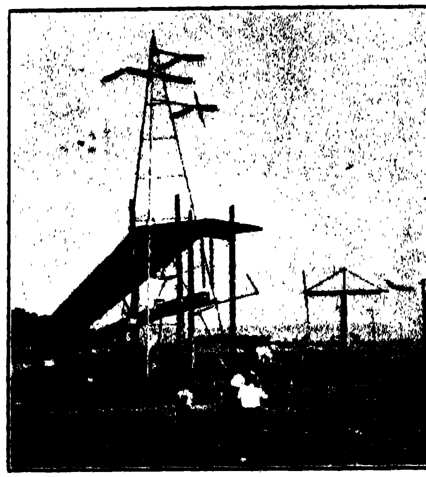
ARTIFICIAL LIGHTNING

Recently, a small group of electrical engineers from the General Electric Company have been carrying out field experiments studying the effect of lightning on electrical power transmission lines. The work has been conducted at Croton Dam, in Michigan, where a forty-mile, 110,000-volt line was available as a tool for research. An artificial lightning generator was constructed for use as a portable impulse of 1,500,000 volts.

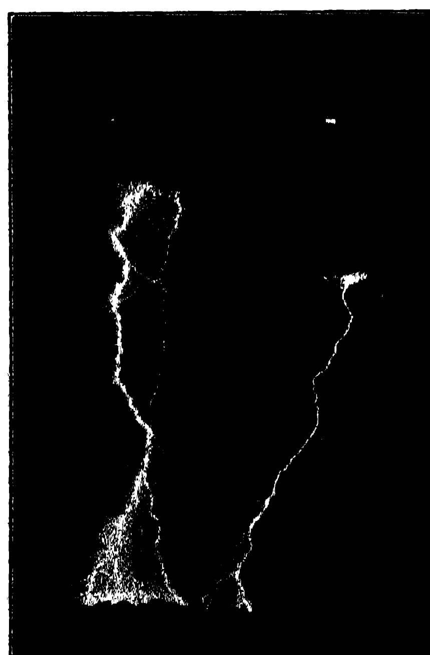
Mounted on a heavy trailer chassis and readily movable anywhere a motor truck might go, this lightning machine can send bolts of artificial lightning over a transmission line with startling reality. It can simulate to a remarkable degree of accuracy the bolt of natural lightning which might at any time strike a transmission line. In other words, it provided the way to take the waiting out of the game for the investigators. Had they been forced to wait for natural lightning, the experiments could never have been performed in the short time available. The equipment made it no longer necessary to wait in some remote place for lightning to come tumbling out of a cloud.

It was needful, also, to design and build a portable cathode-ray oscillograph in order to use the lightning generator to its fullest advantage. The oscillograph—a millionth-of-a-second camera —has the necessary capabilities for making records of the lightning surges over transmission lines. The varied characteristics of lightning waves and surges are studied from these photographic records, and from them engineers are able to make measurements of value in designing lightning arresters.

The lightning generator, once started, was almost automatic in operation. Its movements were governed by a Telechron clock in the circuit, which permitted the generator to discharge its million or one and a half million volts of man-made lightning with clock-like regularity once every sixty seconds. All measurements of the lightning were recorded in millionths or micro-seconds.



THE PORTABLE GENERATOR
CAPABLE OF PRODUCING A MILLION AND A HALF VOLTS.



NATURAL LIGHTNING
"BREAKING" OVER CROTON DAM, MICHIGAN.

THE SCIENTIFIC MONTHLY

OCTOBER, 1932

HEREDITY AND ENVIRONMENT—AS ILLUSTRATED BY TRANSPLANT STUDIES[1]

By Dr. H. M. HALL

IN the announcement of this address the main title has been set down as "Heredity and Environment"; but since I have myself entered the field from the side of taxonomy I ask your permission to begin with this topic and after having outlined the aims of taxonomy and its relation to studies in evolution, to present some results of experiments on effects of heredity and environment, which two factors lie at the very basis of all evolutionary and taxonomic studies.

THE PLACE OF TAXONOMY

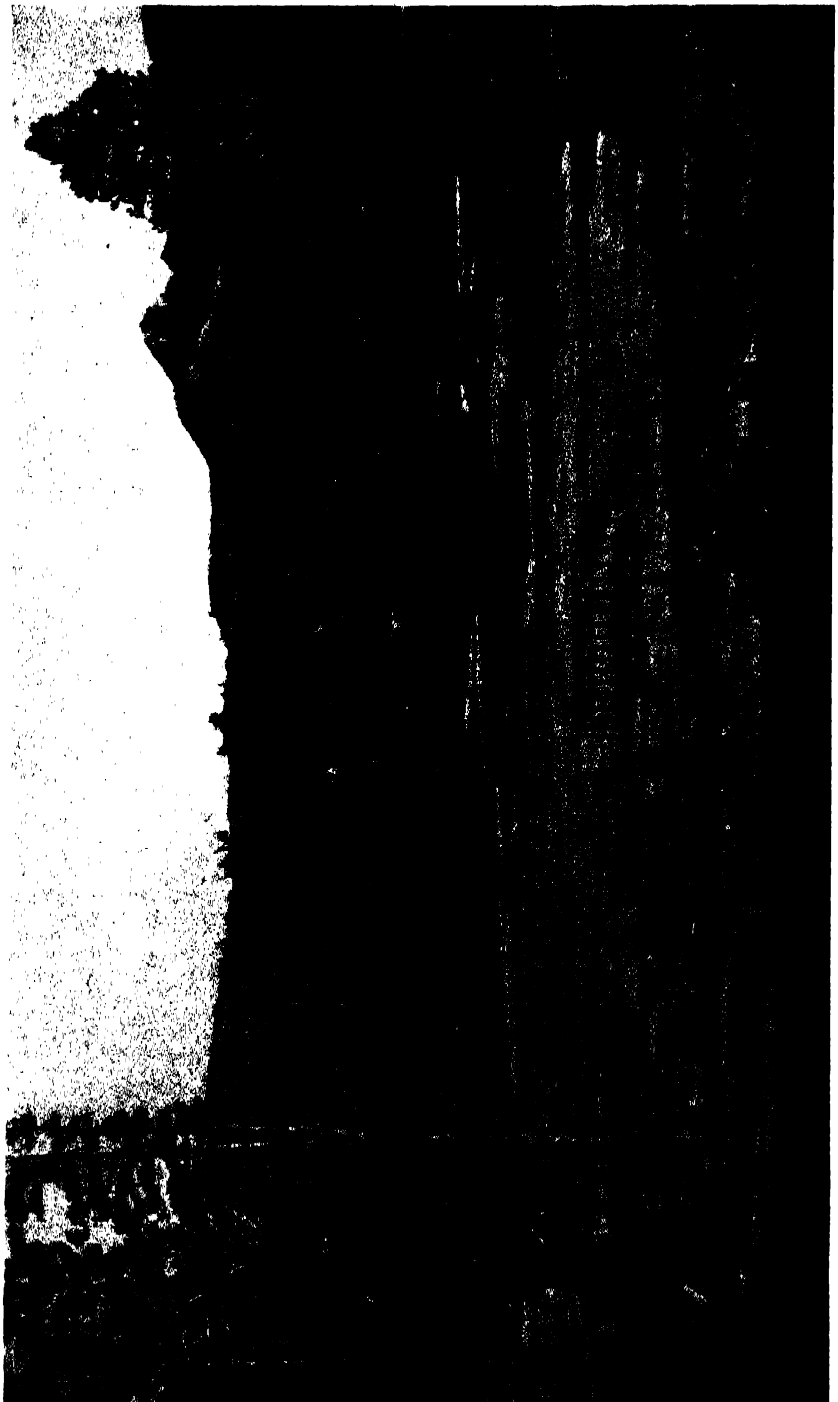
Taxonomy, in the biological sense, is the classification of animals and plants according to their natural relationships and deals also with the laws and principles of such classification. Classification itself may be based entirely upon resemblance or upon any other convenient set of criteria and so may be entirely artificial.

The earliest phase of biological science, so far as we are able now to determine, was the outcome of early man's attempt to classify according to similarities and uses. We find, for example, such a classification in the works of Aristotle, and the mere fact that this early philosopher and biologist sometimes placed marine animals and plants in the same category, because of morphologic resemblance, does not diminish our admiration for his keen insight nor our appreciation of the impetus he and his students gave to the science of classification.

As time went on, the analysis of plant (and animal) characters became more and more refined, and this in turn led to a more and more rational system and to the development of true taxonomy, that is, a classification based upon natural relationship. The idea of evolution also must have had some influence upon classification long before Darwin's time, for even Aristotle pointed out the "unbroken chain" from the lowest forms of life to the highest. But, however this may be, it was not until after the publication of the "Origin of Species" that taxonomists attempted an arrangement based definitely upon the theory of relationship by descent.

It was this coming in of the concept of evolution that gave a new significance and new life to the subject of taxonomy. Up to that time it had been pursued chiefly by physicians and others who recognized the practical value of classification, and by those who, like Linnaeus, were interested in the study for its own sake; but when it became evi-

[1] Prepared for the lecture series of Carnegie Institution of Washington. Due to illness of the late Dr. Hall, it was delivered on December 4, 1931, by Dr. Walter T. Swingle, Bureau of Plant Industry, U. S. Department of Agriculture.



A VIEW IN THE TRANSPLANT GARDENS AT TIMBERLINE STATION, ELEVATION 10,000 FEET.

dent that these more or less natural groups of organisms were the product of evolutionary processes and that each possessed, therefore, a definite although perhaps indefinable blood relationship to every other, it naturally followed that taxonomy took its place as one of the most valuable tools for the student of evolution.

We must not, however, lose sight of the facts that evolution still is a theory, that any classification based upon this theory must be of necessity speculative in its nature and that it will approximate the truth only in proportion to the number of established facts upon which it rests. But the vital point here is that if there be anything at all to organic evolution, then taxonomy is dealing with the products of evolution and it is this that gives to taxonomy both its highest mission and its greatest responsibility.

In the planning of any thorough investigation the first step is to make a survey of the field and to organize the stock of facts already at hand. It is this survey which taxonomists are making and which they offer to the student of evolution; it is an enumeration of the countless forms of life arranged according to natural relationships, so far as these can be determined from available evidence.

But a still more important duty falls to the taxonomist. He, more than any one else, should be intimately informed as to the distribution and the arrangement in nature of the products of evolution—the families, genera, species and especially the subdivisions of species—and hence should be expected to correlate the findings of both speculative and experimental evolutionists with the results of his own field investigations. No theory of evolution or of origin of species can be finally accepted until it explains the origin of the many forms of life as they exist in a natural state.

Thus taxonomy may be said to stand both at the beginning and at the end of the long series of studies on evolution; at the beginning it furnishes the survey and the inventory of evolutionary units; at the other extreme it checks results against the inexorable requirements of the facts of nature.

New Methods in Taxonomy

The conclusions of taxonomy result largely from observation, description and comparison; in other words, they are reached subjectively. There is now an ever-increasing movement to introduce objective methods, especially for the testing of criteria used as a basis for classification. Thus we have application of statistical methods, the methods of serum diagnosis and of biochemistry. Genetics and cytology, although organized for a different purpose, supply incontrovertible facts as to the nature of plant characters.

But this evening I have the privilege of calling to your attention a quite different method for testing the criteria of taxonomy. This we refer to commonly as the transplant method, although I must warn you that it is not to be confused with transplant experiments devised for very different purposes.

The object of the experiments now to be described is not to demonstrate the evolution of one hereditary form from another and much less the origin of one species from another; although it is conceivable that out of them may come evidence bearing upon these important questions of heredity and evolution. They are designed, instead, to furnish definite evidence as to the nature of certain plant characters and the value of these as criteria in plant classification.

Transplant Method in Taxonomy

From this experimental study of plant characters, however, there come results of interest in fields other than taxonomy. These various issues may be

grouped under three general heads, which I shall now briefly enumerate, with some hint as to methods, and then pass to illustrations of the results obtained and incidentally bring out more clearly some of the methods used in arriving at these results.

As the first outcome of present transplant experiments may be mentioned the ability to distinguish between those variations which are not heritable and those which are—*i.e.*, between those temporary modifications that result from the immediate environmental impact and those other features so fixed by heredity that they can not be changed by the environment; or again, between phenotypes on the one hand and genotypes on the other.

For this determination the practice is to select individual plants of the same species, or of closely related species, but which differ in those features which it is desired to test. These individuals are then moved from their diverse habitats into a standard environment, where they are held for some years, under control and under close observation. If, then, the differences vanish, the two forms are shown to be but temporary environmental modifications; but if, on the other hand, the differences persist in the standard environment, they are known to be of a genotypic nature and hence of evolutionary significance.

The second group of returns flowing from the transplant experiments supplies information as to the extent to which the habitat may modify plant characters without necessarily affecting the genotypic constitution. This knowledge is of prime importance both to taxonomy and ecology and is best obtained by moving an individual plant into as many different habitats as possible (Fig. 1).

This is easily accomplished with perennials subject to vegetative division; for these divisions may be grown simultaneously at the seashore, in interior valleys, at various altitudes in the mountains, in sun and in shade, in moist and in dry soil, and, in fact, the original individual may thus be subjected to as great a variety of environments as one's facilities will permit. In practice, the only restriction is avoidance of conditions to which plants are not subjected in nature, for teratological effects are here to be avoided. The results are best studied by taking photographs and specimens from all the divisions and

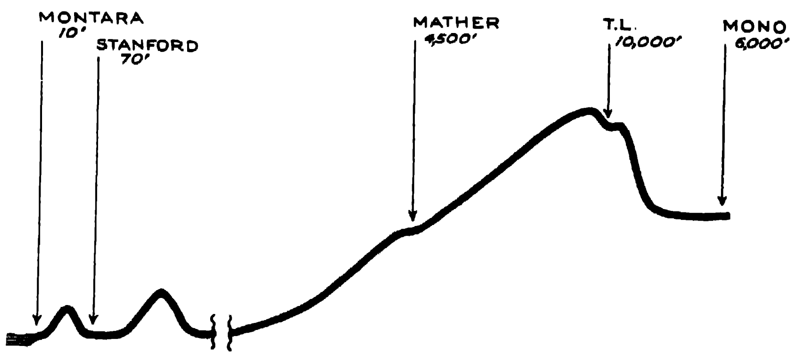


FIG. 1. PROFILE OF THE AREA IN WHICH TRANSPLANT STATIONS ARE LOCATED WITH ELEVATIONS INDICATED IN FEET ABOVE SEA-LEVEL. FROM LEFT TO RIGHT: PACIFIC OCEAN; MONTARA STATION; CENTRAL LABORATORY AND GARDENS AT STANFORD UNIVERSITY; BREAK IN LINE INDICATES THE WIDE SAN JOAQUIN VALLEY; MATHER STATION IN THE SIERRA NEVADA; CREST OF THE SIERRA AT 12,500 FEET; TIMBERLINE STATION (T. L.); AND THE MONO STATION IN THE ARID GREAT BASIN.

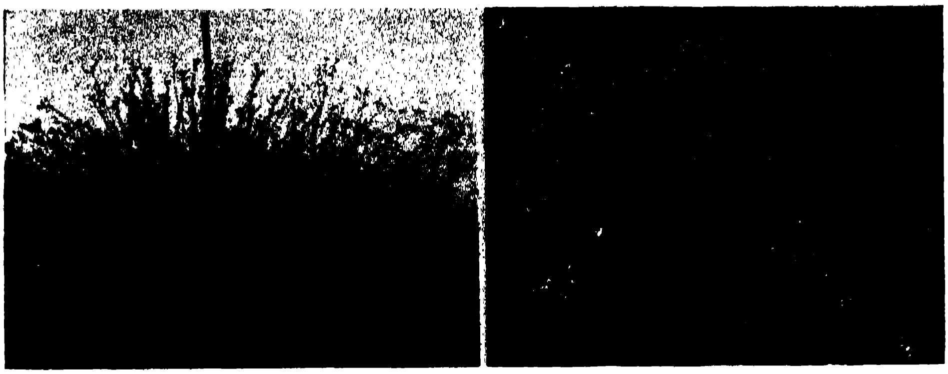


FIG. 2. MODIFICATIONS IN THE HABIT OF *HAPLOPAPPUS VENETUS*
THESE INDIVIDUALS ARE NOW GROWING TOGETHER IN THE GARDEN. IN ITS NATIVE HABITAT THE PLANT ON THE LEFT WAS DECUMBENT, THE PLANT ON THE RIGHT WAS ERECT. THE FORMER HAS NOW BECOME AS ERECT AS THE LATTER, WHICH HAS REMAINED UNCHANGED.

comparing these between themselves and with a specimen of the original, preserved as a control.

With information at hand as to the heritable nature of the characters of any plant and also as to the extent to which environment may modify these characters in the individual, it is seen very plainly that each organism is the resultant of two important forces, namely, heredity and environment. In fact, each organism, as we see it, is the result of or balance between these two opposing forces. This vision of the organism as a balance is most forcibly impressed upon one engaged in transplant experiments.

The third result of these experiments is a better knowledge of the composition of species and genera. The assembling of natural variations necessitates much detailed field exploration with its re-

FIG. 3. THREE TYPES OF *ZAUSCHNERIA*
DIFFERING PRINCIPALLY IN LEAF-WIDTH. FROM LEFT TO RIGHT THESE ARE: *Z. latifolia*, *Z. californica* AND *Z. microphylla*.

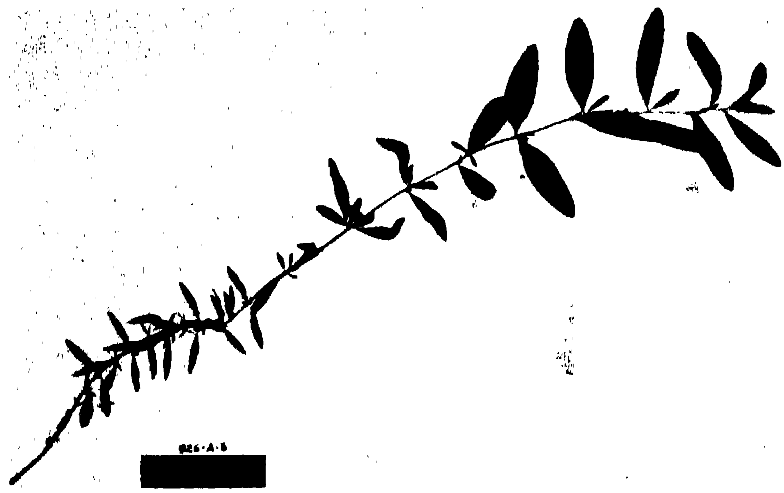


FIG. 4. MODIFICATION ON A SINGLE SHOOT OF *ZAUSCHNERIA*
LOWER, NARROW LEAVES RESEMBLE THOSE OF ORIGINAL FORM AT LOMPOC, CALIFORNIA. THESE WERE PRODUCED WHILE PLANT WAS GROWN AT A COASTAL STATION. UPPER, BROAD LEAVES WERE PRODUCED AFTER TRANSPLANTING TO DRY SHADE AT MATHER, CALIFORNIA. THE LOWER LEAVES WOULD CLASSIFY THE PLANT AS *Z. californica*; THE UPPER ONES AS *Z. latifolia.*

sultant information as to number of forms involved, their ecologic relations and their geographic distribution at the present time. The assembling of these variations into standard environments at one or more of the transplant stations encourages one to make direct comparisons between them after they have been stripped of all differences brought about by the immediate effect of their former habitats. In this manner there is obtained definite information as to relative length of steps between the forms. This information can not be gained by other means of investigation.

In summarizing to this point, it may be said that experiments have been devised and put into operation which lead to a better understanding of plant characters and forms, especially through the means they furnish, first, of distinguishing between effects of heredity and environment and for recognizing the balance between these two forces, and, second, for determination of the extent to which environment may modify heritable features. Through use of these results and from data obtained from geographic distribution there is derived a knowledge of the ecologic and genetic units constituting species and genera.

The general result from experiments and field studies thus far made in California has emphasized the fact that within many species there is a vastly larger number of heritable variations (genotypes, ecotypes, races, etc.) than has been assumed and that the classification of these can not be satisfactorily made by current methods of taxonomy. On the other hand, it is found that environment plays a large part in molding the organism within the limits set by hereditary factors. Although no evidence has been found to prove that environmental forces may induce permanent (genotypic) change, there is no reason to exclude this as a possible factor in evolution.

ILLUSTRATIONS OF THE METHOD

As examples directly applicable to classification, there may now be cited

two sets of experiments which helped to determine the taxonomic status of certain forms of *Haplopappus,* a genus of the *Compositae* which I myself had the temerity to monograph before this experimental evidence was available. One of these experiments illustrates also the effect of heredity in holding plant characters within bounds; while the other illustrates the importance of environment in making modifications within these hereditary boundaries.

The subject of the first experiment is *Haplopappus squarrosus,* which has two forms. One nomenclatorily typical, but rather rare, grows only near the sea. The other is an inland form and much more common. In my monograph the differences were noted from herbarium and field studies, but taxonomic segregation was avoided for fear that the coastal form might be merely a maritime variation. Since publication, both forms have been brought to a standard environment where they have not only maintained the differentiating characters (five years), but have permitted detection of differences previously overlooked. The results call for separation, at least into subspecies.

Quite different was the case of two forms of *H. venetus.* This shrub is commonly and typically erect. On certain soils, however, it occurs in a decumbent or nearly prostrate form, so different in appearance that it was technically named as a distinct species (*decumbens*), by an earlier taxonomist. This decumbent form when brought into the experimental garden assumes a habit

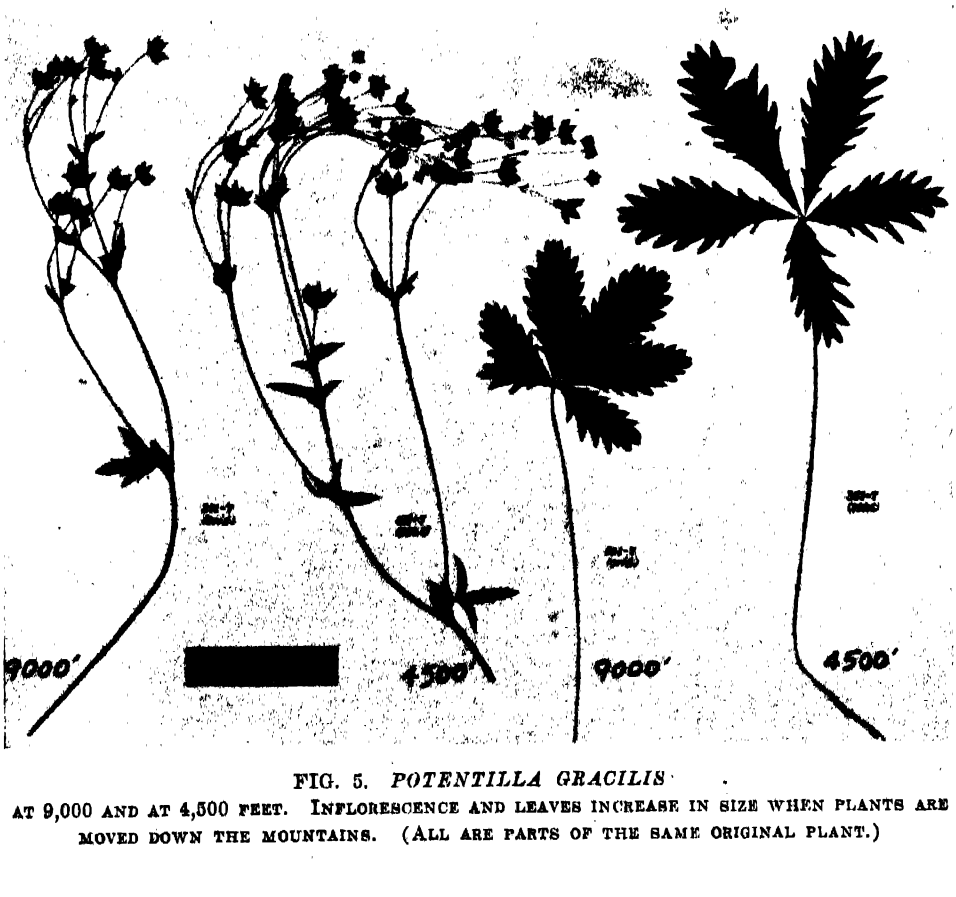


FIG. 5. *POTENTILLA GRACILIS*

AT 9,000 AND AT 4,500 FEET. INFLORESCENCE AND LEAVES INCREASE IN SIZE WHEN PLANTS ARE MOVED DOWN THE MOUNTAINS. (ALL ARE PARTS OF THE SAME ORIGINAL PLANT.)

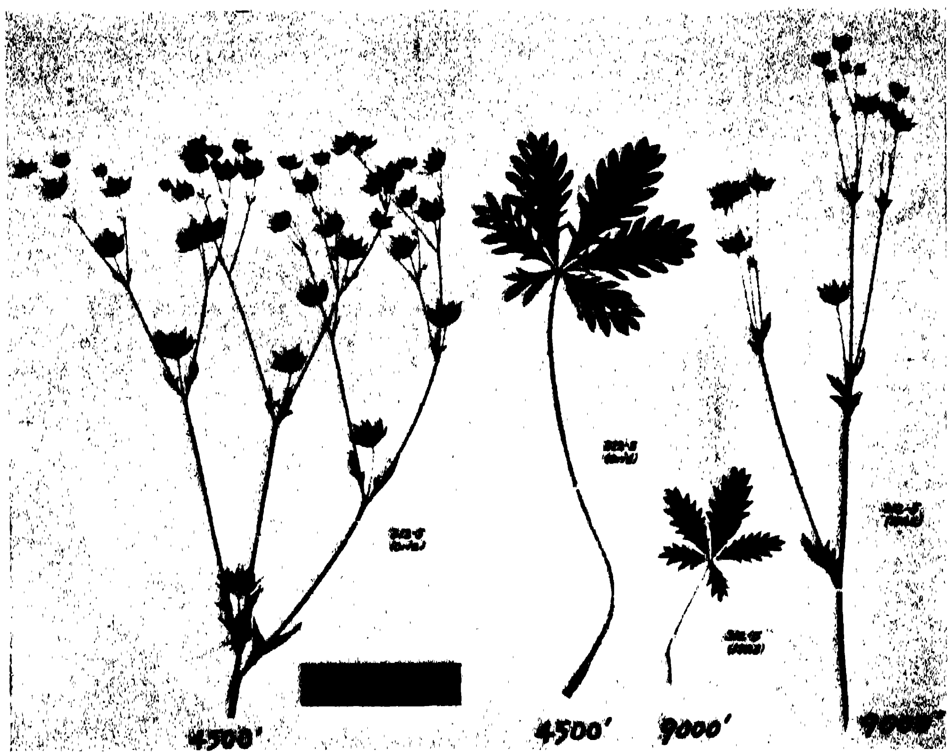


FIG. 6. *POTENTILLA GRACILIS*
AT 4,500 FEET AND AT 9,000 FEET. INFLORESCENCE AND LEAVES DECREASE IN SIZE WHEN PLANTS ARE MOVED UP THE MOUNTAINS. (ALL ARE PARTS OF THE SAME ORIGINAL PLANT.)

as strictly erect as that of the common form growing beside it in the cultures.

Thus these simple though time-consuming experiments lead to definite conclusions as to the nature of the characters in question and leave no doubt as to the taxonomic treatment of the forms involved.

Now in order further to illustrate methods for distinguishing with certainty between hereditary and environmental forms, we come to a most interesting as well as beautiful genus of western American plants. Even the name holds our interest, although it can not be said to be beautiful, for the genus is *Zauschneria,* a member of the evening primrose family, named in 1831 in honor of the Bohemian botanist, Zauschner.

In our investigations to date, 134 of these hereditary types have been discovered and many times this number may be expected from future exploration. All these 134 types have been transplanted to a testing garden at Stanford University, and there, under a common environment, each is found to retain its peculiar characteristics.

If the most unlike forms are compared the differences are so great as to lead one to look upon them as distinct species; but when all are arranged in a single series the steps separating each from its neighbors are so slight that it is impossible to assign them to different groups. In this case heredity sets very narrow limits so that changes in the environment have little effect.

The influence of the habitat in mold-

ing plant characters is also illustrated with *Zauschneria*. Some botanists have proposed that as many as 22 species should be made in the genus, while others, more conservative, have proposed three as the correct number. If three are accepted, these would be *latifolia*, with broad leaves, *californica*, with leaves of intermediate width, and *microphylla*, in which the leaves are very narrow. But these differences may be due to environment and not to heredity, for plants with moderately wide leaves (*californica*) have been moved into partly shaded gardens where they produced leaves so wide that the plants would thereafter be classed as *latifolia*, and similar modifications have been induced in other forms.

The investigations in *Zauschneria* have not been designed to give a conclusive answer to the very debatable question as to whether modifications induced by the environment may become hereditary in time. But thus far no changes have been induced by environmental conditions which have the appearance of becoming hereditary.

Potentilla rupestris is another widespread species whose representatives in the western United States have been subjected to transplant experimentation for several years. From the one hundred and sixty or so members of this Linnean "species" that have been assembled for study, at least sixty-five genetically distinct forms have been detected.

Another member of this genus, *Potentilla gracilis*, may be used to illustrate the methods employed in making reciprocal transplants. A plant was moved from 9,000 feet down to 4,500 feet in the Sierra Nevada. This did not

FIG. 7. *POTENTILLA BREWERI*

SHOWING INCREASE IN NUMBER OF LEAFLETS AND OF INCISIONS. THE TWO LEAVES AT LEFT ARE AVERAGE ONES TAKEN FROM THE PLANT IN ITS ORIGINAL HABITAT AT 9,000 FEET ALTITUDE (1923). THE TWO LEAVES AT RIGHT ARE AVERAGE ONES TAKEN FROM A DIVISION OF THE SAME PLANT THAT PRODUCED THE ONES AT LEFT, BUT AFTER IT HAD BEEN TRANSPLANTED TO AN ALTITUDE OF 4,500 FEET (1928).

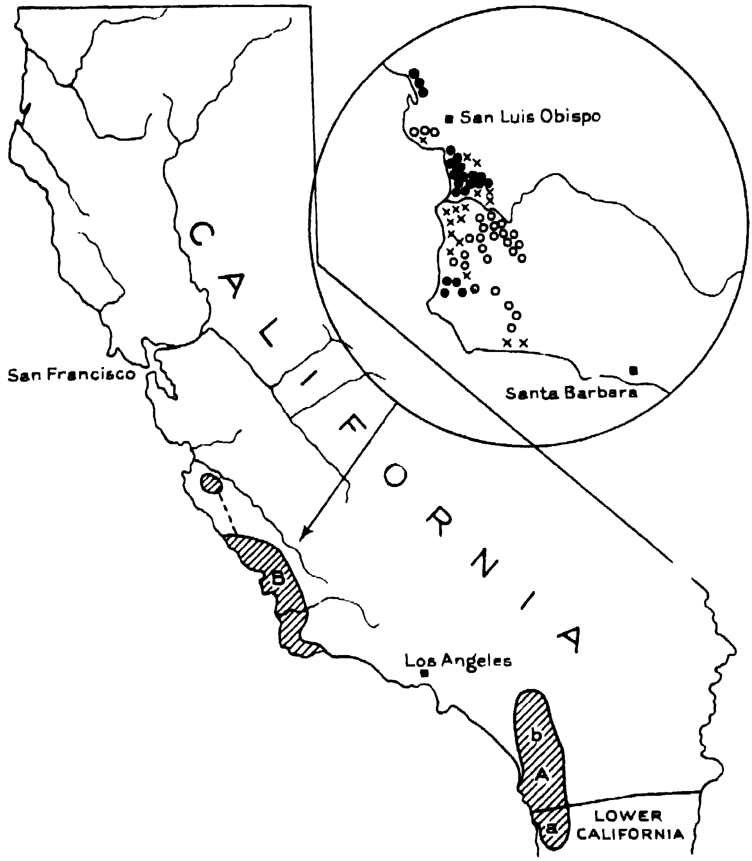


FIG. 8. DISTRIBUTION OF THE FORMS OF *HEMIZONIA PANICULATA*
A. SOUTHERN SUBSPECIES, SOUTHERN AND LOWER CALIFORNIA—(a) THE MOST SLENDER FORM: FIXED, AS SHOWN BY EXPERIMENT; (b) A LESS SLENDER FORM: FIXED, AS SHOWN BY EXPERIMENT. B. NORTHERN SUBSPECIES, SANTA BARBARA TO MONTEREY. INSERT CIRCLE SHOWS PART OF ITS AREA ON A LARGER SCALE; (a) INTERIOR, EIGHT-RAYED FORM (INDICATED BY CIRCLES); (b) COASTAL, THIRTEEN-RAYED FORM (INDICATED BY DISCS); (c) HYBRID COLONIES (INDICATED BY CROSSES).

change the number of leaflets or of dentations, but it did greatly increase the number of flowers and consequently of seeds and offspring, as shown in Fig. 5. That this was not due merely to better conditions in the garden was shown by the results in the reciprocal transplant. An individual of the same species originally growing at 4,500 feet was moved to the exact habitat of the former at 9,000 feet. The effects of this change on the parts was to decrease the number of flowers, while the number of leaflets and of dentations remained constant, Fig. 6.

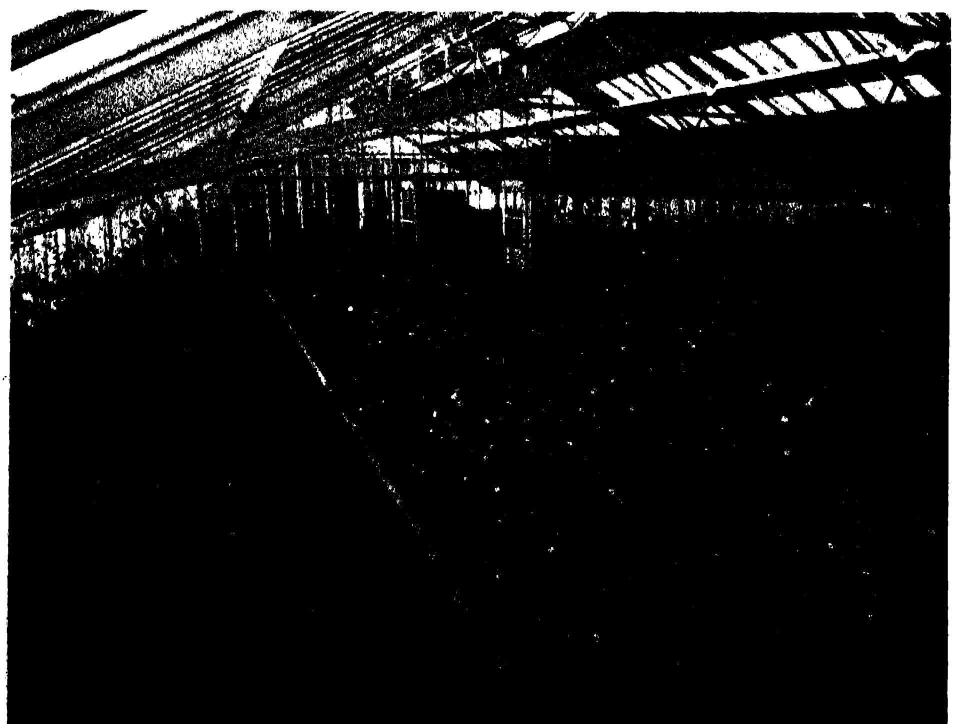
In another species, *Potentilla breweri*, however, it was possible to modify the number of leaflets by moving an individual from 9,000 feet to 4,500 feet, as is shown in Fig. 7.

MODIFICATION OF NATIVE VEGETATION

Some of the most interesting results have been obtained with the common California tarweeds. These are mem-

bers of the subtribe *Madinae* of the *Compositae*. When grown side by side at the transplant station these show amazing diversity in size, method of branching and general appearance, in spite of being grown under identical soil and climatic conditions. That these are not among our attractive wild flowers there can be no doubt, and perhaps the question has arisen in your minds as to why these homely weeds were selected for the experiments. This was partly because they are so abundant in the region where we happen to be located, partly because they can easily be grown from seed, partly because they are so plain and useless that man has not mixed the breeds in an attempt to improve them; but most of all it was because some of the species grow only in alkaline soil and around salt marshes where they have escaped the encroachment of civilization. Thus far man has been too busy modifying and destroying the native vegetation on areas suitable for browsing, grazing, agriculture or subdivision into town lots to concern himself with these inhabitants of unattractive corners of his domain.

It is remarkable that even in the West it is almost impossible for the biologist to find undisturbed areas for his investigations or to select a group of organisms in which all the forms still exist in their original condition. When one attempts to trace evolutionary lines, every connecting variation is of the utmost significance. It is therefore necessary, even with these tarweeds, to select groups where the lines have not been broken, and too often these can be found only in species of the alkaline



GREENHOUSE WITH TARWEEDS AT THE CENTRAL STATION OF THE DIVISION OF PLANT BIOLOGY, CARNEGIE INSTITUTION OF WASHINGTON.

wastes or in those which by chance may be present in such desolate places as the old neglected cemeteries; and, if one is to judge from man's present progress in the desecration of nature, the biologist of the future will be fortunate indeed if he be permitted access even to the alkali flat and the cemetery.

As an example of the modification on the native vegetation caused by man, attention may here be called to one group of tarweeds (*Hemizonia villosa* and its relatives), which formerly occupied arable soils of the California valleys, as evidenced by specimens preserved in herbaria and by a few plants still living in out-of-the-way corners. But some of the variations represented in the collections of early botanical explorers are no longer to be found, and doubtless many others no longer existent were overlooked by those pioneer botanists. After 20 years of search it has been decided that the gaps are too great to justify even a speculative reconstruction of evolutionary lines. It is possible that by genetic analysis of the remaining forms and the building up of new combinations through crossing, some clue might be had as to these lines, but the results would forever lack the confirmation which can come only from researches in taxonomy and geographic distribution.

Steps in the Evolutionary Processes

We turn to the consideration of results flowing from the experimental investigation of taxonomic units. It happens that the example now to be given clearly illustrates also the high

A CORNER OF THE TRANSPLANT GARDENS IN THE SIERRA NEVADA AT MATHER, ELEVATION 4,500 FEET.

value to science of preservation of natural conditions. It concerns a species of *Hemizonia* which has persisted in, we hope, all its natural forms. It is *Hemizonia paniculata*, a species not hitherto suspected of having variations of evolutionary value. There are such variations, however. Although few, they are sufficient to indicate very concisely what are taken to be steps of varying lengths in the formation of species. A special virtue of this case is that the differences may be expressed in numbers, and the facts, if not the conclusion, may therefore be determined in an entirely objective manner.

By coupling experiment with field studies on this tarweed we gain a vision of species in the making or at least of the different degrees of separation between related forms within the species.

The situation is shown in the map of the coastal district of California (Fig. 8). One is at once struck with discontinuity in distribution. Over the considerable area from above Santa Barbara to Riverside, not a single plant of this species can be found, so that there is a definite barrier between plants of the north and those of the south. This distribution is correlated with differences in morphologic characters. The northern plants are the more robust and regularly have more disk-flowers than those of the south. These differences are retained when both are grown together in a standard environment.

Thus the species is geographically and morphologically separated into two subspecies with no intergradation.

More interesting from an evolutionary point of view are the smaller variations within each of these subspecies. For example, the southern subspecies has two forms, one slender and small-flowered, occurring in Lower California. The other, less slender, occurs north of the Mexican boundary. Since these are heritable forms, as experimentally proven, we see that there has been an evolutionary segregation at about the line of the Mexican boundary.

But it is in the northerly subspecies that the most definite segregation has taken place, definite because capable of numerical expression. The difference lies in the number of ray-flowers. This has been determined at many localities, at each of which the number has been counted usually on 100 plants. On the map the circles indicate colonies where number of ray-flowers is regularly 8; the black discs where they are 13. At these localities there is no gradation from the one to the other. There is slight variation around 8 and 13, respectively, but no meeting or overlapping. The separation is complete.

But quite different is the situation at certain other localities, represented by the crosses. Here the number of ray-flowers centers around neither 8 nor 13, but varies between these extremes, with a majority approaching sometimes the one, sometimes the other. These colonies which link the 8-group and the 13-group are of much significance.

In full realization of the risk one runs in drawing conclusions from field observations, even when supported by garden experiments, as these have been, with these facts before us, we can at least glimpse something of the evolutionary processes which have been going on within this group of plants. As I see it, the steps were somewhat as follows:

First, the separation into two subspecies, a northern and southern, with a barrier between is very clear. Then the breaking up of the southern of these into smaller units is less clear-cut, owing perhaps to retention of contacts along the border. In the northern subspecies there has been a sharp segregation into two forms and a subsequent coming together of these at certain localities where, probably through hybridization.

there have been set up colonies which the taxonomist would class as "exactly intermediate."

Balance between Heredity and Environment

The various illustrations that have been given may serve to offer a glimpse of the complexity of forms as they occur in nature. Every plant and animal is the product of two very unlike and variable influences. One influence is that of its ancestors. This is heredity. The other comes from its home. This is environment. Heredity sets the limits of the influences of the environment. Environment decides the position within these limits. Some traits for which heredity sets wide limits may be profoundly changed; others for which heredity sets very narrow limits may be changed only by changing the heredity itself through some process of breeding. In studying the history of the development of organisms on the earth by means of the classification of the products of evolution, it is of capital importance to know with certainty how far heredity controls and how far environmental conditions control the traits under consideration, for it is only through heredity that ancestral influences are expressed and evolutionary relationships are revealed.

THE ELUSIVE RUFFLE PLANT, RIELLA

By Dr. R. A. STUDHALTER

TEXAS TECHNOLOGICAL COLLEGE, LUBBOCK, TEXAS

For almost a century, a ruffle standing on end has been playing an interesting game of hide-and-seek with the botanist. Elusive and sly, this anomalous plant has managed to keep out of the clutches of the scientist and, since it is too small to attract the attention of the layman, it has nothing to fear at his hands. Beautiful and shy, it has tried to escape to the four corners of the earth, only to be run down again by the heartless collector. And once found, it has on occasion used the tactics of a sly fox and managed to give up its habitat and thereby elude further search for several decades. The plant is still in the lead in the hide-and-seek game, and the botanist must be content with playing as best he can the poor hand which nature has given him out of a stacked deck.

One of the rarer of the several hundred thousand known plants, and certainly among the most anomalous in form and structure, this bright green ruffle nevertheless has one of the most prosaic of names—Riella, after Du Rieu de Maisonneuve, but suggesting a river or brooklet. True to its name, the first Riella to be seen by the writer was growing in the fresh waters of a creek in the Davis Mountains of western Texas. This stream, locally called Madera Creek, is hemmed in by very steep canyon walls hundreds of feet high and its waters run, now precipitously, now lazily, in a northeasterly snake-like path fifteen hundred feet below the summit of the adjacent Timber Mountain. During the summer rainy season they form a torrent for a few hours after a hard downpour; but during the greater part of the year they trickle rather slowly over the intervening rocks and sand from one shallow pool to another, or else they disappear beneath the sands on leaving one pool only to reappear in a second one a hundred or two yards below. During the summer rains, the unbroken current can be traced from its source near Mount Livermore, also called Baldy Peak, which holds its head 8,382 feet above sea-level, for ten miles or so to the abrupt mouth of the canyon at an elevation of 4,500 feet, and then over the level, treeless plain. The latter part of the course is ordinarily a dry sandy and rocky creek bed, and in the ascent of the creek water can not be found until the shade of the high canyon walls retards the excessive evaporation so ruinous on the plain, and permits a good cover of grasses, shrubs and even trees.

It was in the shaded canyon of Madera Creek that Riella was first seen by the writer, forming a solid green mat extending from several inches below the water in a small, shallow pool on up the sandy bank to a distance of three feet beyond the water's edge. Here, evidently, was an aquatic plant which had been completely submerged during the several months when unusually heavy winter and spring rains had kept this little pool twice or thrice its present size. It was apparent, further, that during the last few days or weeks the water level in the pool had sunken, leaving the bulk of the beautiful green carpet, two inches in thickness, fully exposed to the air. Holding an individual plant, an inch or so in length, to the sun, it proved to be quite thin and transparent, leading one to infer that the carpet can not endure very long out

FIG. 1. A TYPICAL SHALLOW POOL OF MADERA CREEK IN THE DAVIS MOUNTAINS OF WESTERN TEXAS, IN WHICH THE COMPLETELY SUBMERGED *Riella americana* WAS FOUND. PHOTOGRAPH BY PAUL D. VOTH.

of water, for the sand and gravel on which it was growing could not remain moist enough to supply the needed water for the simple system of rootlike hairs growing out from the base of the ruffle.

An accidental and unusual find, one must consider this; but what is this strange, green ribbon or ruffle standing on end, so unsymmetrical in appearance, with a thickened "stem" and a very thin "wing"? For the moment it was impossible to say with certainty even to which of the four major groups of plants this anomalous form belongs; but if one must guess, he would like to place it in the Bryophytes, among the liverworts. That this ignorance was not so inexcusably profound is indicated by the reaction of one of the best botanists in the country who stated, upon seeing our specimens, that he would hardly have recognized the plant as a liverwort.

On the same day the plant was found in abundance submerged in other parts of the creek (Fig. 1); at no time in the five years following has it been seen to form a carpet outside of the water, and it has become less abundant every year. So far as known, this species, *Riella americana,* occurs at the present time only in the upper reaches of Madera Creek, from the mouth of the canyon toward its headwaters.

Our curiosity was aroused to determine how much was known of this rare plant, and to know something of its relatives. As known at the present time, the genus Riella is composed of not more than twelve species, which may prove to be a mere half dozen. The nearest geographical neighbor to the American species is the one found in the Canary Islands. Others occur in Algeria, Morocco, Tunis, Sardinia, Greece, Switzerland and France. Almost as far distant as Texas from this Mediterranean center of distribution are Turkestan and South Africa, each of which

harbors a single species. At the present time, Algeria leads, with four species.

These several species are so nearly alike that there is no question of their belonging together in a single genus, which is the only representative of the family Riellaceae. Although it is associated taxonomically with the family Sphaerocarpaceae, one may assert that Riella is structurally a much isolated plant. It is, indeed, so peculiar that the taxonomists have never agreed on its position in the plant kingdom. It has been shifted back and forth between the Marchantiales and the anacrogynous Jungermanniales, or has been placed with Sphaerocarpus into a distinct primitive group, or more recently has been considered quite advanced and placed with the acrogynous Jungermanniales. Such shifting is the inevitable fate of all anomalous organisms.

A number of unusual situations have arisen in connection with the discovery of Riella in various parts of the world. The first known form was found by De Notaris in Sardinia in 1834. It appears that only a single collection was made and that there are no herbarium specimens in existence from this locality; we rely upon Montagne's rather imperfect description of the form. More than half a century later, Müller identified as this same species, *R. notarisii*, a single incomplete collection made in Greece in 1887. Otherwise, the species has succeeded completely in eluding the botanist.

This first known of the Riellas foreshadowed much of the future history of this remarkable genus. Virtually all the species are rare. *R. paulsenii* from Turkestan has been collected only once, and that under very strange circumstances, while several other species have become lost, only to be found again at a much later date. *R. reuteri* of Switzerland may be considered the classical example of a lost form. Discovered on the banks of the Lake of Geneva by Reuter in 1851, it was collected at intervals for several years. Later a mill was erected over the single small muddy spot in which it had grown, and for decades the species eluded all search, both here and elsewhere. It is said that the Schloss Bartholoni now occupies the site. When rediscovered, it was again in possession of a very limited area further up the Rhone valley where, according to Meylen, it is once more in danger of being exterminated by the "improvements" of man. Fortunately, other Riellas, formerly considered distinct species but believed by Trabut to be morphological variations of *R. reuteri*, are present in France and northern Africa.

The French form was similarly lost for over twenty years, at which time it was found not only at its original site but in another location at some distance in the same province.

The American species was first described from a collection made in 1902 by Earle and Tracy in Limpia Creek in the Davis Mountains, although Schott had gathered some specimens of the plant in the same creek in 1855, and Saunders had made a single collection of it in South Dakota in 1898. Between 1855 and 1902 the plant was not seen in the Davis Mountains, and after the latter date it was once more lost until 1927. These losses may be attributed in part to the small number of botanists to visit this region; but this is not the only explanation, for between 1902 and 1927 the organism left its original home in Limpia Creek completely, either jumping across the mountain range to Madera Creek, or else being more successful in remaining in Madera, where it had not been seen until 1927. The plant has evidently disappeared from South Dakota, as it did from a temporary lake near Lubbock, Texas, where it was found for a single season. The American species has, then, become lost from three localities, and apparently is

present now only in Madera Creek; again, aside from the specimens obtained in Madera and near Lubbock since 1927, only three collections are in existence.

Few species of living organisms which have been studied by the professional biologist have not been seen in their native lands, and yet *Riella paulsenii* of Turkestan has been seen only once, in Denmark. At the turn of the last century, the biologist Paulsen collected a number of samples of mud from ponds in Bokhara in the hope of obtaining resting stages of crustacea. Three years later, in 1901, when the mud was cultured in an aquarium in Copenhagen, crustacea were obtained in abundance, but also a new species of Riella, described by Porsild. The culture became contaminated and lost, with the consequence that this organism has been seen but once, twenty-five hundred miles from its home. This species holds the record of all the Riellas for its aloofness.

That such an anomalous situation should be closely paralleled is almost unbelievable. Nevertheless, about the same time a quantity of mud was collected near Port Elizabeth in Cape Colony, South Africa, also for the purpose of obtaining crustacea. In 1903, six years later, a culture made in England from this mud yielded a new species of Riella, described as *R. capensis* by Cavers. The botanist has been more successful, however, in his onslaught on the South African species, for it has since been found in relative abundance in the temporary bodies of water called vleis on the Cape Peninsula and the Cape Flats. This appears at present to be the most abundant species of Riella. Mud sent from this same region by Miss Stephens to Dr. Chamberlain at Chicago for algae yielded hundreds of *R. capensis* plants thirteen years after collection.

It is quite evident, then, that Riella is an exceedingly rare plant, and one is not surprised that it has been seen by few botanists. Because of its anomalous structure and perhaps because of its rareness, the literature on the genus has become rather voluminous. Its morphology has aroused the interest of such masters as Hofmeister, Montagne, Leitgeb and Goebel, whose researches were often of necessity based on few plants or even on dried herbarium specimens soaked in water. Living material, and especially viable spores, were at a premium.

It is of peculiar interest to note that among all the Bryophytes, including both liverworts and mosses, *Riella clausonis* (now called *R. parisii*) was the first plant in which the fusion of gametic nuclei during fertilization was observed. This work of Kruch in 1890 was also the very first case among all plants in which it was observed that before the fusion of fertilization the male and female nuclei undergo such changes that their respective chromosomes are clearly visible.

A more detailed examination of the several species of Riella shows all of them to have the same basic form, namely, an elongated stem-like structure on one side and over the top of which extends a very thin wing, and from the base of which grow a number of rootlike hairs, the rhizoids (Fig. 2). The stem is round or oval in section, and the wing is a single cell in thickness. The latter extends over the top and side of the stem in much the same manner as an unbroken row of feathers in the headdress of an Indian might extend from his forehead over his head and down his back; to make the parallel more accurate, however, the solid ribbon of feathers should be thought of as starting under the chin and forming a wavy band over the face and head and down the back almost to the ground. The feathers under the chin are very short, and they become progressively longer over the head and shoulders, and

FIG. 2. *RIELLA AMERICANA*

At the left, a male plant with the male sex organs or antheridia near the outer margin of the wing; at the right, a female plant with the attached non-sexual sporophytes in various stages of development; at the lower center, outline of a single asexual plant enclosed within its pear-shaped involucre. Drawings by S. Flowers.

again gradually shorten near the ground. It is this upright wavy wing which led Barnes to call Riella a ruffle standing on end; and Hofmeister considered *R. helicophylla* of Algeria, in which the wing is sometimes wound spirally around the stem like a spiral stairstep, one of the most remarkable forms in the vegetable kingdom.

In some species the plants are monoecious; that is, they have both male and female organs on the same individual. In others, as in the American species, the two sexes constitute different individuals, which, in their general form, are similar. The male sex organs or antheridia, each of which develops a large number of sperms, occupy a very unique position, since they occur in a row on the outer margin of the wing, which is here somewhat thickened; in other words, they are found near the tips of the Indian's feathers, somewhat comparable to the eyes in the feathers of a peacock. The youngest of these are found under the Indian's chin, and they are progressively older over the top and back of his head. In the female individuals, the outer edge of the wing is unthickened; the flask-shaped female organs, the archegonia, are found attached to either side of the stem near its upper extremity. Each archegonium contains an egg in its swollen basal portion.

A knowledge of the life history of

other liverworts would lead one to feel certain that the fertilized egg does not develop directly into another individual like the parents from which it had its beginning. Indeed, the zygote grows by numerous cell divisions into an altogether different kind of individual, a sporophytic or spore-bearing non-sexual plant, which in no manner resembles the gamete-bearing ruffle; its size, form, structure, and the number of chromosomes contained in its nuclei when they are dividing, are all different. Instead of being ribbon-shaped, it consists of a stalked globe. Instead of having rhizoids growing into the soil, the base of the stalk consists of absorbing tissue embedded in the stem of the ruffle-like plant. In other words, it is never a free individual, but shows parasitic tendencies, although it remains green through a part of its life span and can therefore manufacture at least a part of its own food. As it matures, it occupies a successively lower relative position on the stem of the ruffle, not by any power of shifting its position, but by the continued elongation of the stem of its gametophytic mother on which it is a partial parasite.

The globular sporophyte produces in its interior a large number of spores, which develop at the expense of a number of adjacent cells. The latter act as "nurse" cells; that is, their protoplasm and walls break down and serve as food for the developing spores. A mature spore is thick-walled and covered with numerous spines, which have been thought of as aids in the dissemination of the plant by becoming attached to aquatic animals or floating vegetation. In Texas, however, they seem also to aid in preventing too great a dissemination and consequent loss since, if they did not become attached, they might be swept down the creek and out of the canyon into dry areas where they have little chance of germinating and growing. They do not always germinate readily, but may retain their vitality for many years.

The ultimate product of the germination of the spore is again the gamete-producing plant or ruffle. But such is the perversity of nature that few plants or animals grow immediately into a stage resembling the adult in shape and structure. Such juvenile states often give a clue to the ancestry of an organism. During its development, Riella passes through several distinct stages before it takes on the form of the adult.

The first stage after germination consists of a cylinder of green cells arranged end on end, with a long one-celled rhizoid growing in an opposite direction. Does this filamentous stage refer back to an algal ancestry many millions of years ago? By their fruits they may be known, but also by the juvenile forms through which they pass.

Next, the young growing plant assumes the shape of a paddle or tennis racquet one cell in thickness, which may be compared with some of the simplest thallus bodies among the other liverworts.

True to its reputation for anomalous structure, the next stage is completely unexpected. If Riella were to continue to grow along the tennis racquet plan, it might, indeed, produce a highly complex structure. Increase in size might be accompanied by the establishment of dorsiventrality and by the formation of air pores, complex air chambers, a midrib, a definite notched apical growing point and many other structures seen to-day in the more common liverworts. But development along any of these lines would result merely in a slight variation from the structures found in Marchantia and other hepatics. Who knows but that the ancestors of Riella started out on such a plan of keeping up with the Joneses—or perhaps they were the Joneses with which other liverworts were trying to keep up. At any rate, these early progenitors apparently de-

cided that, to be different, development must proceed along a new line, even if some of the gains previously made must be sacrificed in the change. So they hit upon a plan, unknown anywhere else among the liverworts, of absorbing most of the broadened part of the tennis racquet and starting a new lateral growth from its base. It is this anomalous lateral sheet one cell in thickness which grows directly into the stem and wing of the adult plant.

The filamentous stage shows radial symmetry, or symmetry around a line, while the tennis racquet stage shows bilateral symmetry, or symmetry on the two sides of a plane. The adult stage has no symmetry at all, as viewed from the side; but a bilateral symmetry becomes apparent as a result of a plane cutting the stem in half and extending out through the middle of the wing, cutting this structure into two equal halves, each a half cell in thickness.

In such a complex manner is the life cycle completed. The ruffle produces the sex cells; fertilization is followed by growth into a globular spore-bearing partial parasite; and the spore develops again into the ruffle form through successive filamentous, thalloid and lateral-outgrowth stages.

Among the several species, much variation is shown in the habitat occupied. Some live near sea-level, while others are found in the mountains, up to 5,500 feet. Some occur in brackish waters and others can tolerate only fresh waters. Many of them are found only in temporary bodies of water, but the Texas form is not at all averse to living in the permanent pools of Madera Creek. They are aquatic and are normally found submerged; but they may be able to live for a time out of water, with the drying of the lakes or streams. While some of them grow readily in culture in the laboratory, others do not, and it has not yet been found possible successfully to transplant *R. americana* from Madera Creek to Musquiz Creek or to its former home in Limpia Creek. Several of the species have been found among aquatic vegetation, but the Texas form prefers to grow in almost pure stands, neither mixed with other plants nor shaded by floating algae. Little is known about the reaction of these organisms to light, temperature and soil and water conditions. In some respects they seem able to adjust themselves to extremes, as is the case with the Texas species, which grows normally in the cool waters of a well-shaded canyon but was found for a time in the warm waters and the intense sunshine of a playa lake near Lubbock, Texas, and at another time under a three-inch sheet of ice. Nothing is known about the factors responsible for the very local distribution of the various species and for the disappearance of some of them.

For a plant as rare as Riella, one is surprised to find that it is, in a sense, almost world-wide in its distribution. Found in both northern and southern hemispheres, and in both eastern and western, four of the six continents are represented. And yet the genus has been found in only eleven countries, and in almost every instance, except South Africa, a given species occurs in only one or two very local areas. Not over twelve species occur in not over eleven countries.

The geological origin of the Riellas is hidden in the haze of the past. It would scarcely be expected that a soft-bodied form could leave behind a fossil record as easily as a woody trunk or a stony fruit, and definite fossil records of any liverworts are consequently rare. Nevertheless, there has been a belief among many botanists that the liverworts as a group are old geologically. During the last few years, several excellently preserved though not fruiting liverworts have been found dating as far back in geologic times as the Car-

boniferous; tissue structures were beautifully shown in these fossils. Such discoveries raise a faint hope that in the course of time even some fossil Riella-like plants may be located.

Any theory of the geological origin and distribution of a genus which lacks all representation in fossil form is, of course, purely hypothetical. It is, nevertheless, hoped that the ideas presented in this connection may serve as a point of departure in building up a hypothesis of the geological origin of Riella, even though the present state of our knowledge will permit neither their proof nor their disproof.

Starting with the concept that the liverworts have been in existence through a number of geologic ages, we find some evidence for the belief that the genus Riella itself is not a very young one, but that it has gone through a long evolutionary history. Thus, a new genus is rarely present in the northern and southern hemispheres, and in the eastern and western; it usually requires many ages for it to become disseminated into four continents. Neither would a new genus be expected to have its species adapted to a variety of habitats, for such adjustments also require time. Again, while the liverworts in general exhibit juvenile stages in their development, Riella reaches its adult condition by a much more indirect and circuitous route, in that it passes through three distinct and unlike stages before it reaches the adult form of the ruffle. It is a generally accepted principle that each of these stages represents a relic of an ancestral condition, and that the larger the number of such stages the older is the plant likely to be geologically. On such a basis, the ruffle structure is a highly derived form and in no sense primitive. And finally, a cue may be taken from the flowering plants of the Canary Islands; a very large percentage of this flora is a relic vegetation, left over from earlier geologic periods. Perhaps *Riella affinis,* which is found only in the Canaries, is a similar relic. For these reasons, it seems rather logical to see in Riella an ancient plant, a landmark on which is recorded the structural history of an ancient race.

Probably history began to unfold itself for the ruffle plant in those ancient lands which are now southern Europe and northern Africa. All but three of the species are still there, not having deserted the land of their birth. Just how long ago this event occurred, it is impossible to say; probably several geologic ages before the Pleistocene ice swept in repeated waves over northern Europe and America, a certain liverwort began to show tendencies toward that anomalous development which was finally to culminate in the present ruffle plant. Conditions for the growth of this primitive organism must have been favorable and, with the passing of the ages, it became wide-spread. Since the agents of dissemination of the present species are not definitely known, the agents in the ancient world can only be postulated. Primitive birds must have migrated to an extent, and there is no reason for denying their ability to carry spores attached to the mud on their feet then, as now. Liverwort spores have been found in relative abundance on the feet of water birds. Such an active agent was aided, no doubt, by the more slovenly changes in climate, land levels and the size of land masses.

One can imagine the ancestors of Riella crossing the forerunner of the Mediterranean either by the agency of birds or by numerous short steps around the edges of the sea or across land bridges. From this Mediterranean center, the plants became distributed in all directions. Transport on the feet of birds seems the most logical explanation for their migration to the Canary Islands. Between southern Europe and Turkestan are numerous bodies of

water and many mountain streams; probable similar conditions ages ago afforded plenty of opportunity for a series of short jumps, aided by water birds. Crossing the Sahara region and the equator presents a more knotty problem, but not an insurmountable difficulty. It is well known that many European families and genera of the higher plants, the seeds of which are many times as heavy as the spores of a liverwort, have made the same jump to the region of the Cape of Good Hope; a period of more uniform climate or a series of jumps from one mountain range to the next offers a likely explanation.

The passage to America is the most difficult to explain. There is good evidence for the supposition that the bulk of the genera of plants both in Europe and America were at one time, during a period of mild climate, located in a mythical region far to the north. From this center of dispersion, identical or similar plants migrated southward into the two hemispheres, east and west. Perhaps the ancient Riellas also succeeded in extending their range into this birthland of the north from which they could migrate, along with the higher plants, into North America. At such a time the genus must have had a very wide range, covering possibly most of the northern hemisphere. Under favorable living conditions, the number of species was probably much greater than now. Then came the ice ages, driving the plants southward and eradicating many of the species. Some of them, perhaps, were able to adjust themselves to a cold climate, in which connection one is reminded of the Texas plant growing for a time under an ice sheet. But most of the species became extinct as a result of the onslaught of the several periods of glaciation. If the species in the western hemisphere were ever numerous, they have been reduced to a single one.

The few species of Riella which are left in existence to-day are true plant orphans, left to shift for themselves in a world which is none too kindly toward them. Each has gone its separate way, having lost all track of its brothers similarly stranded in other countries. And yet one wonders whether a systematic search may not reveal a much wider distribution, so that the present gaps between the Mediterranean region and Texas, South Africa and Turkestan may not be filled with other habitats for the known species, or for species yet to be discovered.

These considerations, combined with the disappearance of some of the species for many years, lead one to the conclusion that the genus Riella is dying out, that it represents the last stand of a race which is finding this age too unfavorable for its existence. If this hypothesis be true, the ruffle plant is likely in another geologic age to be shelved in the antiquarian records along with Lepidodendron, Sigillaria, the dinosaur and the mastodon.

BULLETS AND SPEAR-HEADS EMBEDDED IN THE TUSKS OF ELEPHANTS

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INTRODUCTION

I HAVE long been interested in foreign bodies embedded in the tissues of fishes. Years ago I found a mummified pipefish and later the backbone of a fish each held in the mesenteric folds of a fish. These and other like data were brought together and published in 1922 with the title, "Foreign Bodies Found Embedded in the Tissues of Fishes."[1] However, long before this I had dissected 54 sting-ray stings and 4 catfish pectoral spines from the jaw muscles of a hammer-headed shark.[2]

And finally I recently dissected a pair of jaws of the black-tipped shark from the Gulf of Aden with like surprising results. In these jaws and the adherent muscular tissues—the jaws had merely been "roughed out" and dried—I found 13 sting-ray stings. Three of these were embedded in the gum-like tissues (technically the "thecal folds") surrounding the teeth. But most surprising was it to find a fourth spine embedded in the solid cartilage of the jaw. These spines had produced interesting abnormalities in the corresponding rows of teeth of the shark which will be described in another paper. The general account of their inclusion in the jaw tissues of this shark has been published in the May, 1932, issue of this journal.

Becoming greatly interested I worked through various general odontographies (works dealing with the tooth structures of man and the lower animals) to see what they contained bearing on this subject of tooth abnormalities in sharks. Various interesting things were found in these books, among them several accounts of foreign bodies included in the tusks of elephants. This has led to the running down of all the available accounts, and it has seemed of interest to bring the data together into definite form.

INCLUSION OF BULLETS IN THE TUSKS OF ELEPHANTS

The tusks of the elephant are the permanent upper incisor teeth. They are not only the largest of the elephant's teeth, but in proportion to the size of the body are the largest teeth belonging to any animal. Each tusk consists of two parts; the outer solid part or tusk proper; and the root or the basal part embedded in the upper jaw. This basal part consists of a hollow chamber or pulp cavity filled with blood vessels and nerves. The walls of this chamber, formed of dentine or ivory, are thinner behind where the pulp cavity is largest. These tusks grow at the base from persistent pulps throughout the life of the elephant, their increase in length being checked only by the wear and tear of fighting and of uprooting trees.

The presence of bullets in the tusks of elephants is not very uncommon. This phenomenon has been known for hundreds of years to ivory workers who have found them in cutting up the tusks. Ivory is one of the most prized of the commodities which are luxuries. The greater part of the ivory of commerce is

[1] *Natural History*, Vol. 22, pp. 552–557, 6 figs.

[2] *Science*, 1907, Vol. 25, p. 1005.

obtained by shooting the elephants which bear it. The intent is to have the bullets enter the heart or the brain, and it is in these latter that we are most interested since many of them find lodgement not in the brain or head but through bad aim or movement of the animal they penetrate the tusks. This matter has been well put by Dr. George F. Kunz in his interesting book, "Ivory and the Elephant."[3] Dr. Kunz has examined scores of specimens which justify the title of this section. After noting that thousands of elephants have been killed for their tusks, "which are, so to speak, the animal's jewels," he continues as follows.

"A very curious circumstance is that not uncommonly there is found buried in the tusk an iron bullet which was intended to kill the animal but which got no farther than a lodgement in the very thing the hunter aimed to possess." Then he brings forward the following general statement, based on an examination of many specimens, which will serve as an admirable introduction to this part of my article:

> These specimens afford good evidence that many elephants are struck by shots but are not killed. In other words, judging from the number of tusks showing encysted iron or lead bullets, it is self-evident that these were not the bullets that ended the animal's life; of course the wounding of the tusk would at most give an elephant a powerful shock, and unless the shot that hit the tusk were closely followed by another to the brain, the animal would escape practically uninjured, and when the tusk had been traversed by the ball the direction usually indicates that it could not have inflicted a mortal wound even if its momentum were not too much lessened by the resistance of the ivory it had passed through. Instances of recent shooting showed that the ball had shattered the tusk and this had regrown, thereby proving that the bullet in question had not been that which had killed the elephant.

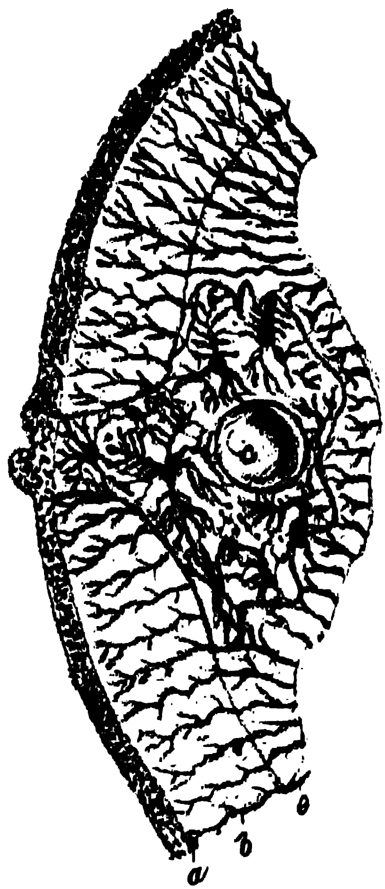
In presenting the data showing the development of our knowledge of this interesting phenomenon, the chronological order will be followed. Probably a search through the old natural history books in which the elephant is referred to would reveal accounts of embedded bullets dating back into the 1600s. But the earliest account I have chanced upon dates back only to 1729.

In that year Frederic Ruysch published at Amsterdam his "Thesaurus Magnus & Regius qui est Decimus Thesaurorum Anatomicorum." On page 36 of this, he speaks of having (presumably in his museum) a section of an elephant's tusk in which was found a brass or copper ball which had penetrated it "explosione sclopeti." Fig. 8 of his plate II portrays the ball and its capsule of secondary dentine but not the tusk. This figure is the earliest representation of this phenomenon known to me, but it is too crude and insignificant to be reproduced herein. Later on, figures will be reproduced showing how such a ball penetrates the tusk, how it becomes embedded and how the orifice becomes closed.

Next Daubenton, in the first edition of Buffon's "Histoire Naturelle,"[4] says, under the heading "Un morceau d'ivoire renfermant une balle de fusil," that in the "Cabinet d'Histoire Naturelle" there is a section of elephant's tusk containing a rusty iron ball "qui a cinq à six lignes de diamètre." Behind the ball the ivory is disturbed and compressed for about 7 lines (seven twelfths of an inch). The ball by its impact had thus formed a kind of tubercle or callus entirely foreign to the structure of the tusk. The tusk was thicker at this point than anywhere else. There was no mark anywhere of the method of entry. He was certain that this ball had been embedded in the tusk for some time. No figure is given.

[3] New York, 1916, pp. 222–225.

[4] Paris, 1754, vol. IX, pp. 161–162.



—*After Goodsir, 1844*

FIG. 1. A BULLET EMBEDDED IN AN ELEPHANT'S TUSK

A DIAGRAMMATIC DRAWING TO SHOW HOW THE BULLET IS COVERED OVER AND HOW THE APERTURE IS FILLED. FOR EXPLANATION OF THE LETTERS SEE THE TEXT.

The next account chanced upon is in A. G. Camper's "Description anatomique d'un eléphant mâle."[5] Camper had seen in the collection of the Prince of Orange a triangular section of an elephant's tusk with two iron bullets included. These lay loosely side by side in a cavity without trace of entrance passage. Our author himself possessed a piece of tusk with an embedded leaden ball. There was nothing to indicate how it had found entrance. These bullets had penetrated the pulp cavity and gradually had become covered over by deposited material, which, however, did not fit closely to the balls.

Camper's figures, while not the first published to show such inclusions, are the first that I have been able to find. However, neither of them is particularly interesting and as better ones will be reproduced later in this article, it does not seem necessary to reproduce them in here.

Next comes J. F. Blumenbach,[6] who, after giving several untraceable citations about inclusions of iron balls in elephants' tusks, states that he possessed such a specimen. Much more interesting was his specimen of a tusk as large as a man's thigh containing an unflattened leaden bullet. This lay in the cavity of the tusk covered over with a sort of rind of stalactitic material. The external perforation which the bullet had made was closed as it were by a cicatrix. He gives no illustration.

Cuvier, in his "Eléphans Vivans et Fossiles,"[7] notes that it is not at all unusual to find bullets included in the tusks of elephants without any trace of aperture by which they found entrance, and says that there was such a specimen in the Paris Museum. (This of course may have been the specimen described by Daubenton in 1754). These data are repeated in his "Ossemens Fossiles,"[8] where he notes that there are three specimens in the Muséum d'Histoire Naturelle. Unfortunately, he also gives no figures.

Goodsir in 1844 wrote the first defi-

[5] In Pierre Camper's "Oeuvres," Paris, 1803, Vol. II, p. 160; pl. 22, fig. 6; and pl. 27, fig. 11.

[6] "Handbuch der Vergleichende Anatomie," Göttingen, 1800, p. 42.

[7] *Annales Museum d'Histoire Naturelle*, 1806, Vol. 8, p. 115.

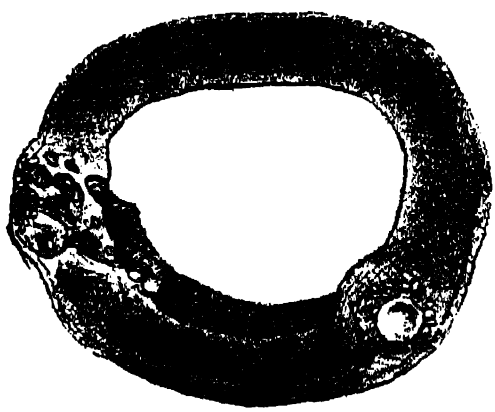
[8] New ed, Paris, 1821, Vol. I, p. 48.

nite paper known to me "On the Mode in which Musket-Bullets and other Foreign Bodies become Enclosed in the Ivory of the Tusks of Elephants."[9] His material came from the cutlery firm of Rodgers at Birmingham, which imported the ivory for knife and razor handles. Goodsir goes minutely and at least in part histologically into the mode of regeneration by which the aperture is closed and the ball surrounded with ivory. It is not the purpose of this article to go into these histological details; however, it would seem that a reproduction of Goodsir's general statement and of some of his figures with their somewhat detailed legends will make clear his conclusions and will illuminate the subject.

One thing detected in all his specimens was of importance as affording a clue to the method of enclosure. This is that

> . . . in none of the specimens are the bullets or foreign bodies surrounded by regular ivory. They are in every instance enclosed in masses, more or less bulky, of a substance which, although abnormal in the tusk of the elephant, is nevertheless well known to the comparative anatomist, as occupying the interior of the teeth of some of the other mammals, and usually considered to be ossified pulp. It was evident that the pulp had ossified round the bullet, as the first step towards the separation of the latter from it. In one specimen the bullet has become enveloped in a hollow sphere of this substance, on the surface of which the orifices of medullary canals are situated. [Fig. 4 herein]. In other specimens the irregular ivory, which surrounds the balls, had become smooth on its surface, the medullary canals had disappeared and the regular ivory had been formed in a continuous layer over the surface of the mass. In one tusk a cicatrix was seen occupying the hole through which the ball had passed, a circumstance which, when seen in similar specimens, has greatly perplexed anatomists. It was observed, however, that, in this instance, the shot had passed through that part of the tusk which had been within the socket; and bearing in mind that the tusk is an organ of double growth, it appeared probable that the shot had been plugged up from within by the ossified pulp, and from without by the continued growth of cement, without any regeneration of the displaced ivory; a hypothesis which was afterwards verified by examination.

Two of Goodsir's figures will here be reproduced. Fig. 1 shows a ball embedded in a tusk. Here *a* is the layer of cement; *b*, the primary or regular ivory with its so-called Retzian tubes; *c*, the ball; *d*, the irregular ivory with its system of tubes and cells; *e*, the secondary regular ivory. Fig. 2 is a cross-section of the base of a tusk showing how a bullet has passed through one wall of the tusk to become embedded in the one opposite. The orifice has become filled with irregular ivory covered on the outside with cement. Here the track of the ball has not become ossified as it has in some other cases figured on the same plate. The material, filling the orifice

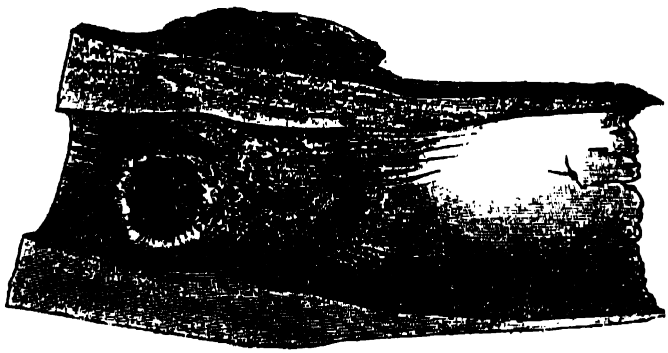


—After Goodsir, 1844

FIG. 2. ANOTHER TUSK WITH AN EMBEDDED BULLET

A SECTION OF THE BASE OF A TUSK IN WHICH THE BULLET HAS PENETRATED THE LEFT WALL, HAS CROSSED THE CAVITY AND HAS BECOME EMBEDDED IN THE RIGHT WALL. THE HOLE HAS BECOME FILLED WITH IRREGULAR IVORY COVERED WITH CEMENT EXTERNALLY. THE BALL IS EMBEDDED IN REGULAR IVORY.

[9] *Transactions Royal Society of Edinburgh*, Vol. 15, pp. 93–100, pl.



—*After Bland-Sutton, 1910*

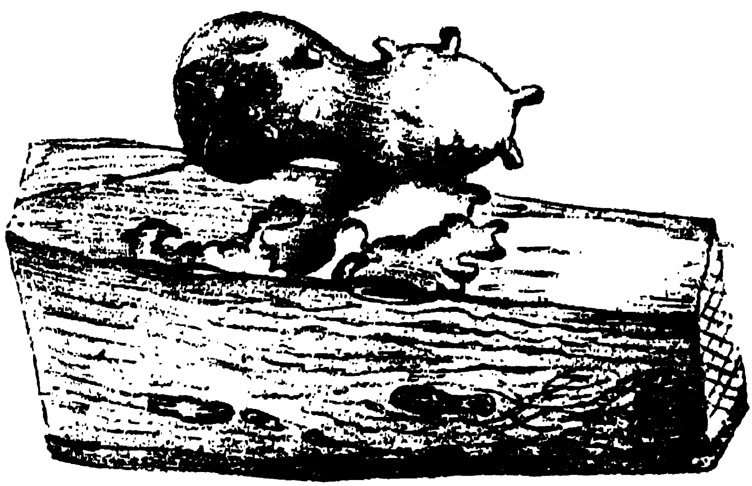
FIG. 3. BASE OF A TUSK WITH AN EMBEDDED BALL

AN IRON BALL PROJECTS INTO THE PULP CAVITY OF A TUSK WHERE IT HAS FORCED OUT OF PLACE THE IVORY LINING. ON THE OUTSIDE IS A WART-LIKE MASS OF DEPOSITED MATERIAL. SPECIMEN IN MUSEUM OF THE ROYAL COLLEGE OF SURGEONS OF GREAT BRITAIN.

and covering over the ball, has become deposited by the regenerated pulp.

J. Bland-Sutton, in an interesting article on "The Diseases of Elephants' Tusks in Relation to Billiard Balls,"[10] figures two fragments of elephant's ivory in which iron bullets are embedded. The better of these two figures is reproduced herein as Fig. 3. Here the bullet has partly broken through the wall of the tusk into the pulp cavity, the point mushrooming the inner layers of the base of the tusk into the pulp cavity. On the outside is seen a nodule,

[10] *The Lancet*, London, 1910, pt. 2, pp. 1534–1537, 7 text-figs.



—*After Goodsir, 1844*

FIG. 4. COPPER BALL ENCLOSED IN AN IVORY SPHERE

IRREGULAR IVORY HAS BEEN DEPOSITED AROUND THE BALL WITH CANALS, SOME CLOSED BUT OTHERS OPENING INTO THE PULP CAVITY OF THE TUSK. THE MASS IS ATTACHED TO THE WALL AND IN TIME WOULD HAVE BEEN ENCLOSED IN IT.

probably of cementous material, deposited to close up the aperture. Bland-Sutton further states that such inclusions have been known to ivory turners for centuries and then concludes thus:

> The thorough way in which a bullet may be embedded in the solid part of an elephant's tusk, and no mark betray it, is proved by the fact that one has been found in a billiard ball. Such a specimen is preserved in the Museum of Royal College of Surgeons of England.

Kunz (1916, p. 224), in discussing such inclusions as these, says that one of the finest collections known of such wounded ivory is to be found in the Buffalo Museum of Science. In the collection presented by Mr. C. H. Wood there are no fewer than 34 specimens which show inclusions of bullets, etc. Kunz had evidently examined these, for of the effects of the bullets on certain tusks he writes that:

> When the bullets are of lead, the metal is generally scattered more or less, and has affected the ivory differently than in the case of steel bullets. It is said to poison the dentine, frequently causing large exostotic growths, exhibiting strange and abnormal bulbous or spicular forms, and hollow spaces often of large size. These tumors are designated odontoma [bone tumors]. . . . On the other hand, in several instances where steel bullets were found, the ivory was only partly decomposed or absorbed away from the bullet, leaving it loose in a hollow enclosure, thus making a kind of ivory rattle. . . . In a very peculiar instance a flattened bullet was found encysted in the hollow rim end of the tusk, where it was only three-eighths of an inch wide, but a growth an inch through had formed around the bullet.

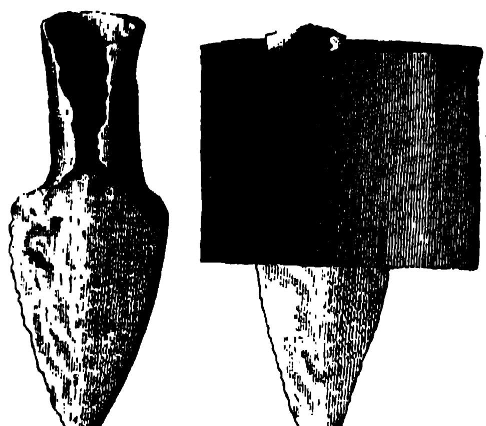
This material in the Buffalo Museum of Science is in the hands of Dr. C. E. Cummings, who is planning an article describing these inclusions. Since this is probably the largest collection in America of such maimed ivory, Dr. Cummings' article will be awaited with great interest.

Such a growth covering a ball, as is referred to by Kunz, is shown in Fig. 3 of Goodsir's plate. Of this, which is reproduced herein as Fig. 4, Goodsir (1841) says:

> A copper ball [is] enclosed in a sphere of irregular ivory, on the surface of which are the orifices of the Haversian canals. Some of the orifices have closed and present the appearance of irregular projections. The mass has begun to be attached to the regular ivory of the tusk, and would in time have been inclosed in it. The ball must either have passed across from the opposite side of the tusk, or must have sunk below the level of the hole by which it entered.

Lastly, C. S. Tomes, in his "Manual of Dental Anatomy, Human and Comparative,"[11] noting that bullets are sometimes found embedded in tusks, offers the following remarks:

> The thin walls of the tusk near its open [hinder] end do not offer very much resistance to the entrance of a bullet; the result of such an injury is not, as might have been expected, the death of the pulp, but in some cases abscess cavities become formed in the neighborhood of the injury, while in others less disturbance is



—*After Combe, 1801*

FIG. 5. IRON SPEAR-HEAD EMBEDDED IN A TUSK

ON THE RIGHT THE SPEAR-HEAD IS EMBEDDED IN THE IVORY. ON THE LEFT IS THE SPEAR-HEAD AFTER EXTRACTION FROM THE TUSK.

[11] Seventh ed., London, 1914, p. 543.

—*After Goodsir, 1844*

FIG. 6. BASE OF A SPEAR-HEAD EMBEDDED IN A TUSK

THE SHAFT OF THE SPEAR HAS BROKEN OFF, AND ONLY THE BASE OF THE HEAD IS VISIBLE. THE TUSK BEYOND THE POINT OF INJURY IS SOMEWHAT DWARFED IN SIZE. FOR EXPLANATION OF LETTERING SEE TEXT OF THIS ARTICLE.

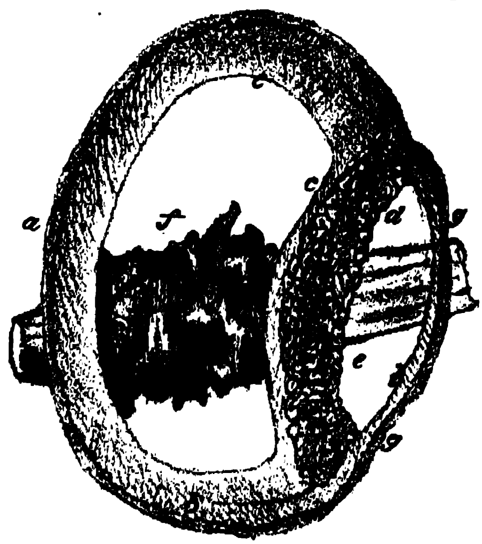
set up, the bullet becoming enclosed in a thin shell of secondary dentine, or sometimes lying loose in an irregular cavity, and round this the normal "ivory" is deposited; upon the outside of the tusk no indication of anything unusual is to be seen, so that the bullets thus enclosed are found by ivory turners only when sawing up the tusks for use.

These explanations are more or less incomplete and before leaving the subject it may be well to quote Goodsir's carefully considered explanations (1841, pp. 97–98). He thinks that foreign bodies enter tusks and are preserved in three ways. Here is his first:

When the ball hits the free portion of the tusk, if it only penetrates to a certain depth of the ivory, no change whatsoever can take place. Neither the cement nor the ivory can be reproduced. In course of time the hole may be obliterated, the ball may be got rid of by wearing down of the ivory, and the ivory under the hole may be strengthened by the formation of new substance. When the ball is detained by the ivory, but penetrates so far as to wound the pulp, the latter ossifies round it, and the ossified portion sooner or later becomes enveloped in new ivory. If the ball penetrates the pulp, the latter ossifies round it, and becomes attached to the hole in the ivory. If the tusk is growing rapidly, and the nucleus of pulp-bone does not speedily adhere to it, the ball will ultimately be situated above the hole. The ball may also pass across the pulp, and become at last enveloped, along with its bony envelope, in the ivory of the opposite wall.

Even more important is his second description and explanation, which will be set out in his own words:

In the second class of wounds, in which the ball enters the pulp-cavity through the socket and side of the tusk, the consequent changes



—*After Goodsir, 1844*

FIG. 7. CROSS SECTION OF TUSK WITH EMBEDDED SPEAR-HEAD

THE SPEAR-HEAD HAS PENETRATED BOTH WALLS OF THE PULP CAVITY (THE ONLY RECORDED CASE), HAS DISPLACED THE IVORY ON THE RIGHT WHERE IT ENTERED AND IN THE PULP CAVITY HAS BECOME COVERED BY A TUBE OF IRREGULAR IVORY. FOR EXPLANATION OF LETTERING SEE MY TEXT.

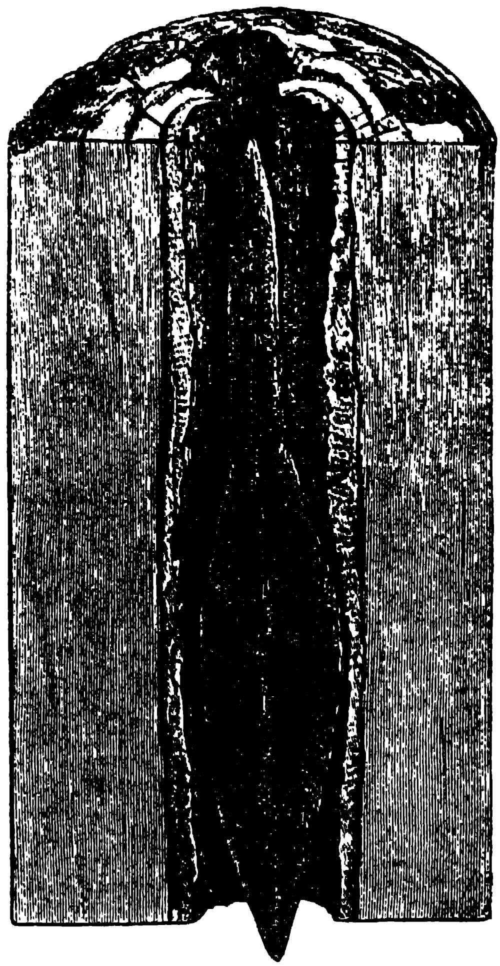
seem to be the following: first, ossification of the pulp surrounding the ball, and the ultimate application of the mass to the hole in the ivory, and, as the latter is necessarily at this part of its extent very thin, the hole is closed; second, the application to the hole in the ivory, and to the surface of the ossified pulp in it, of cement formed by the internal surface of the tusk-follicle. For although the ball may have removed or at least torn the follicle opposite the hole in the ivory, yet, as the tooth advances in the socket, the ball will in time arrive at a sound portion of the latter. There is a specimen on the table which proves that the wounded portion of the follicle may perform this duty sufficiently well. In this specimen the external surface of the cement exhibits a longitudinal fissure, with smooth rounded edges, resulting from the defective formation of cement in the situation of a longitudinal rent or wound in the membrane of the follicle, through which the ball had entered the ivory. The hole in the ivory then being plugged up externally by cement, and internally by ossified pulp, the case proceeds as in the last class of wounds—the ossified portion of the pulp surrounding the ball becoming inclosed in true ivory.

His third explanation pertains to a foreign body which enters from above into the pulp cavity and hence does not wound the tusk. This class of bodies will be considered at some length in the next succeeding sections.

Iron Spear-Heads Embedded in the Tusks of Elephants

So far back as 1801, Charles Combe, of Exeter College, Oxford, gave an "Account of an Elephant's Tusk in Which the Iron Head of a Spear Was Found Imbedded."[12] This tusk was six feet long, weighed 50 pounds and was supposed to have come from Africa. The tusk on being shaken gave out a rattling noise about two feet from the base. It was cut in two in this region and in it was found a much corroded iron spear-head. Combe's figures are reproduced herein as Fig. 5, the earliest known figures of such inclusions in the tusks of elephants. It is also believed that Combe's account of such is the earliest ever published.

The right-hand figure shows a part of the tusk with both ends of the spear-head protruding, while the left-hand

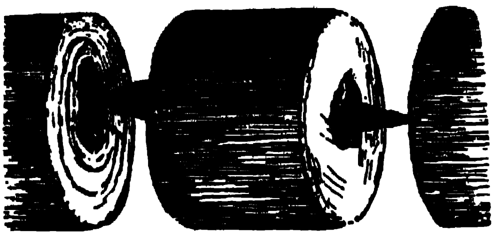


—*After Bland-Sutton, 1910*

FIG. 8. LONGITUDINAL SECTION OF ELEPHANT'S TUSK WITH EMBEDDED SPEAR-HEAD

Here is an iron spear-head, 7½ inches long by 1½ inches wide, embedded in a sheath of secondary dentine. There was nothing on the exterior of the tusk to indicate its presence. Specimen in Museum of the Royal College of Surgeons of England.

[12] *Philosophical Transactions, Royal Society London*, Vol. 91, pp. 165–168, pl.



—*After Tomes, 1914*

FIG. 9. CROSS SECTIONS OF ELEPHANT'S TUSK SHOWING EMBEDDED SPEAR-HEAD

THIS IRON WAS FIRMLY HELD IN THE INTERIOR OF A TUSK, WITHOUT EXTERNAL TRACE OF ITS PRESENCE.

figure shows the much corroded spear-head as it was when extracted from the cavity in which it lay loosely. The presumed manner in which it became embedded will be explained later.

John Goodsir, in an extensive communication on bullets found in the tusks of elephants (which has been considered at some length earlier in this paper), in 1844 figured in his plate a tusk across the base of which he had found an iron spear-head embedded. He does not refer to this in his text but does make things clear in the extensive legends to the figures. In Fig. 6 herein, Goodsir's Fig. 6 is reproduced. Here the reader will see the broken-off base of the shaft (*a*) of the spear. An irregular mass of material (*b*), which Goodsir states is cement, has formed around about the orifice of the wound. Had the shaft broken off deeper in, this cement would have closed the orifice with a cicatrix. This wound has stunted the growth of the tusk which is smaller and weaker beyond the wound, as may be seen at *c–c*.

Fig. 7 is a reproduction of Goodsir's drawing of the tusk in cross-section through the pulp cavity at the base of the tusk. Here the spear-head is separated from the pulp cavity by the deposition of "irregular ivory" (*f*) around it in the form of a tube or sort of Siamese-twin ligature. Here is Goodsir's explanation of figure and phenomenon: *a* is cement; *b–b*, irregular ivory deposited after the tusk was wounded; *c–c*, regular ivory deposited subsequent to the wound; *d*, irregular ivory enclosing a vacant space; *e*, an abscess or sinus continuous with the pulp cavity; *f*, a mass of irregular ivory forming a tube around the foreign body; *g–g*, irregular ivory which has bent outward in drying.

It may be noted just here that this is the only spear-head recorded (in the literature known to me) as being found in any other than a longitudinal position—*i.e.*, one running lengthwise with the axis of the tusk.

The next account of such matters has been found in the article by Bland-Sutton previously referred to (1910). He figures a longitudinal section of an elephant's tusk containing an iron-spear head 7½ inches long by 1½ inches wide. His illustration is reproduced herein as Fig. 8. The specimen is to be found in the Museum of the Royal College of Surgeons in London.[18]

The next account of an embedded spear-head is found in the work by Tomes on dental anatomy previously cited (1914, p. 544, fig.). In the seventh and last available edition of this work, it is stated that this specimen was deposited by its owner, a Mr. Bennett, in the Museum of the Royal College of Surgeons. Tomes's figure of this is reproduced herein as Fig. 9. Here the spear-head has become immovably fixed in the interior of the tusk, there being nothing on the exterior to indicate its existence within. Tomes then quotes a

[18] Neither this nor any other of the specimens noted herein as being in the Hunterian section of this museum, was described in Lowndes' "Catalogue" of the collections of this museum published in 1893. They must have been presented later than that date.

Mr. Erxleben that he know of another such specimen.

In a similar work by J. H. Mummery, entitled "The Microscopic and General Anatomy of the Teeth Human and Comparative,"[14] there is an illustration (Fig. 10 herein) made from a photograph showing such a spear-head inclusion. This seems to be a new specimen never before figured or described. Of it Mummery writes:

> The head of the javelin and a portion of the iron shaft are embedded solidly in the ivory. This specimen was obtained from the ivory worker by a merchant in the City, who could not be persuaded to part with it but lent it to the author to be photographed. There are two somewhat similar specimens in the Hunterian Museum of the Royal College of Surgeons.

Dr. G. F. Kunz, in his interesting book (1915) previously referred, states (p. 224) that Mr. Charles H. Wood had presented to the Buffalo Museum of Science a number of tusks with embedded spear-heads—probably the largest collection of such tusks in America. As stated above, Dr. C. E. Cummings is planning a thoroughgoing report on these inclusions.

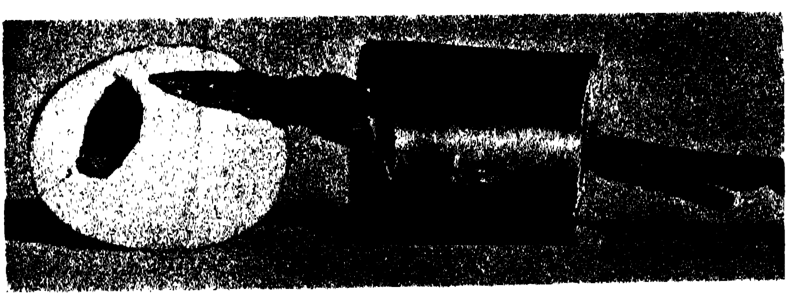
How Bullets and Spear-heads Come to be Found Far Forward in the Solid Ivory

The facts as to these inclusions have been set forth. The manner in which the bullets become embedded is of course clear, but not so the inclusion of the spear-heads, save in one case (Goodsir's). It is now in order to explain this and to show how all are frequently found much farther forward than they were when first introduced. Some hints have been dropped as to this for the bullets, but the whole matter will now be made entirely clear.

The explanation was fairly well set out by one of the first describers of the phenomenon of inclusion. Combe (1801) writes thus

> The most probable conjecture is that the spear entered at the basis of the trunk. If we examine the skull of an elephant, it will be found that the tusks are strongly articulated in the upper maxillary bones. In the males, they reach as high as the thin plate, which separates them from the nasal cavity, whence the tusk arises. We have then only to suppose that the spear struck, somewhat perpendicularly, between the interior angle of the eye and the proboscis; the interposing plate of bone would yield without much difficulty; and the cavity of the tusk is placed immediately beneath.
>
> The presence of an extraneous body in the substance which fills the conical cavity of the trunk, would be the cause of inflammation and subsequent suppuration. In the meantime, the spear-head acting by gravity would descend, till prevented by the resistance of the converging parietes of the cavity. After a process of time, when the tusk had been protruded further from the skull, in consequence of growth, fresh bony matter [ivory] would necessarily be de-

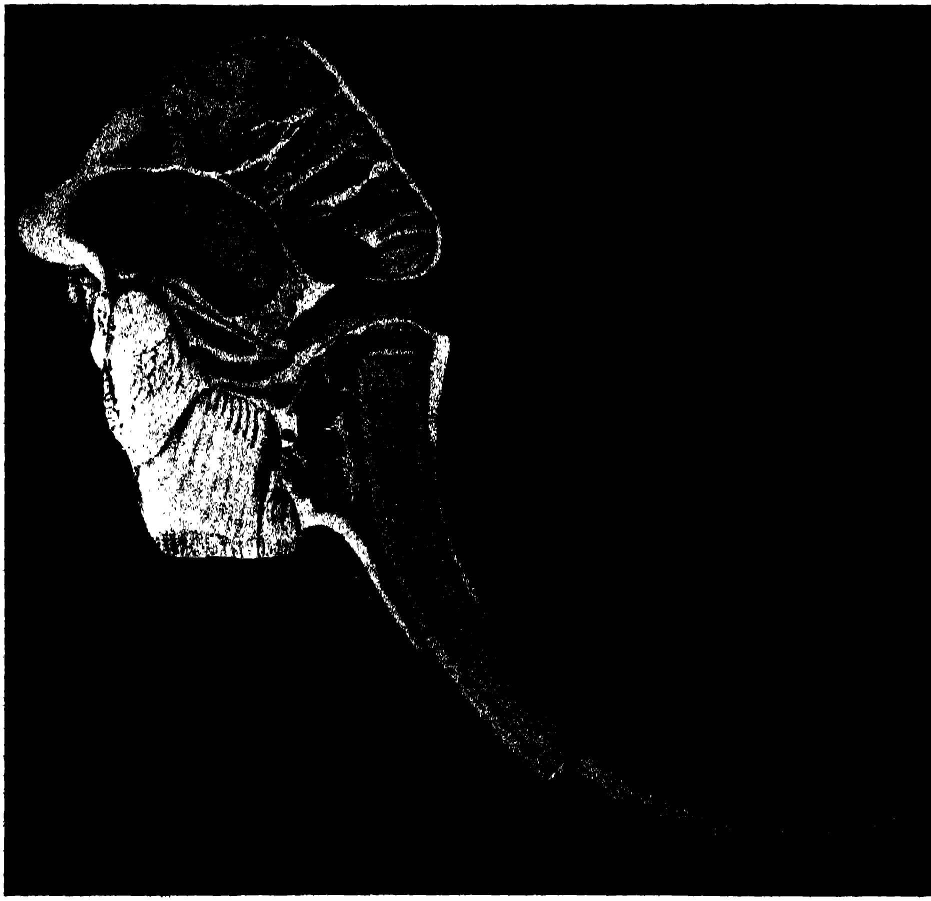
[14] 2nd. ed., London, 1924, p. 231, text-fig.



— *After Mummery, 1924*

FIG. 10. ANOTHER SPEAR-HEAD EMBEDDED IN A TUSK

HERE NOT MERELY THE SPEAR-HEAD BUT ALSO ITS IRON SHANK WAS HELD IN THE IVORY WITHOUT EXTERNAL TRACE OF THE PRESENCE OF EITHER.



—*After Owen, 1845*

FIG. 11. LONGITUDINAL SECTION THROUGH SKULL AND TUSK OF AN ELEPHANT

THIS SHOWS HOW THE TUSK, WITH ITS PULP CAVITY, IS SET IN THE BONES OF THE FRONT OF THE SKULL. ABOVE ITS BASE IS THE NASAL CAVITY, AND ABOVE THIS THE CANCELLOUS BONE OF THE HEAD HONEYCOMBED BY MANY SINUSES. THIS SHOWS HOW A SPEAR-HEAD DROPPED VERTICALLY MIGHT EASILY PENETRATE THE SKULL AND COME TO REST IN THE PULP CAVITY. THE DOTTED LINE IN THE TUSK SHOWS HOW A BALL MIGHT PENETRATE THE PULP CAVITY, WHERE EMBEDDED IT MIGHT BE CARRIED FORWARD UNTIL, EXPOSED BY THE WEAR OF THE TUSK IN UPROOTING TREES, IT MIGHT BE BROUGHT TO THE SURFACE.

posited to preserve a corresponding relation between the size of the cavity and the tusk; and thus the spear-head would gradually become imbedded within the ivory.

The explanation is perfectly sound, but the mode of entrance of the spear-head into the pulp cavity of the tusk will not be wholly clear to the reader who is not acquainted with the osteological make-up of the head of the elephant. What is needed is an illustration showing this, and this is supplied by Richard

Owen.[15] In his "Text" Owen makes no reference to either bullets or spear-heads inclosed in the ivory of elephants' tusks, in fact, he does not seem to have known of the latter, since he makes no reference even to Combe's paper. However, in his "Atlas" he figures an elephant's head and tusk in section to show how the tusk is implanted and to make clear its relation to the other bones of the head. His drawing is reproduced herein as my Fig. 11.

In his long explanatory legend for this figure he effectually makes clear the structure of the head, the penetration of the bullet and how it is progressively carried outward toward the tip of the tusk. Here is his explanation:

> Vertical section of the skull of the Indian Elephant, with the molars and incisive tusk of one side, the latter showing its alveolus and pulp-cavity exposed by a longitudinal section. The dotted line through the fore-part of the pulp-cavity shows where a ball might penetrate that cavity and lodge at the opposite side, be there surrounded by osteodentine, then encased in ivory; and by progressive growth of the tusk be afterwards carried in the direction of the arrow into the middle of the solid exserted part of the tusk. The continuation of the dotted line shows how the ball, if it had penetrated the base of the tusk of a young Elephant, might ultimately be discharged.

Still the question is unanswered as to how the spear-head reaches the elephant and gets into the pulp-cavity at the base of the tusk. This is supplied by Tomes (1914, p. 543–544) as follows for the specimen in the Museum of the Royal College of Surgeons:

> It is to be presumed that a trap was set with a heavily loaded spear, or that it was dropped [by hand] from a tree, with the intention of entering the brain of the animal as it was going to water, both of these methods of killing elephants being practiced in Africa. Sometimes as many as 100 natives are posted in trees and armed with loaded spears, the elephants being driven under the trees by others. But in this case [of the specimen in the Museum of the Royal College of Surgeons] the spear penetrated [easily through the forehead, made of delicate cancellous bone much separated by the multiple large sinuses, and, the handle being broken off, it made its way into] the open base of the growing tusk, which looks almost vertically upwards [see Owen's figure], and then

—*After Bland-Sutton, 1910*

FIG. 12. AN AFRICAN ELEPHANT TRAP

A SKETCH TO SHOW HOW THE AFRICAN NATIVES KILL AN ELEPHANT AS IT VISITS A DRINKING PLACE. THE HEAVILY LOADED SPEAR IS DROPPED ON THE ANIMAL'S NECK OR SHOULDER WHERE IT INFLICTS A TERRIBLE WOUND. SOMETIMES THE SPEAR PENETRATES THE SKULL JUST ABOVE THE BASE OF THE TUSK. WHEN THE WOODEN BEAM IS BROKEN OFF, THE SPEAR-HEAD SOMETIMES DESCENDS INTO THE PULP CAVITY OF THE TUSK.

[15] "Odontography; Atlas," 1845, pl. 146, fig. 1.

the iron part appears to have broken off [from the loaded handle]. This did not destroy the pulp, but the tooth continued to grow, and the iron part, measuring no less than 7½ by 1½ inches, became so completely enclosed that there was nothing upon the exterior of the tusk to indicate its presence.

This particular spear-head referred to, it should be noted just here, is the one refigured from Bland-Sutton (1910) as Fig. 8 herein, and also that referred to in other paragraphs.

—Photograph by Herbert Lang

FIG. 13. AN ELEPHANT TRAP IN THE FOREST SOUTH OF MEDJE, BELGIAN CONGO

NOTE THE GREAT LENGTH AND HENCE GREAT WEIGHT OF THE LOG TO WHICH THE SPEAR IS AFFIXED. FROM THIS ONE CAN JUDGE OF THE TERRIBLE BLOW AND WOUND INFLICTED WHEN IT FALLS. THE TWO LIANAS HANGING DOWN ON EITHER SIDE ARE CONNECTED WITH A TRIGGER WHICH THE PASSING ELEPHANT TRIPS, CAUSING THE SPEAR TO STRIKE IT.

Mummery makes essentially the same statement as Tomes, but neither he nor Tomes gives a figure showing this curious, native method of hunting. This lack, has, however, been supplied by Bland-Sutton (1910), whose illustration is reproduced here as Fig. 12.

That this is not a fanciful sketch may be found by consulting almost any book of adventure and hunting in west central Africa, more narrowly in the Congo. Thus Reginald D. Cooper, in his "Hunting and Hunted in the Belgian Congo,"[16] says of the native ways of capturing elephants that:

> One of these is to use a long, broad-bladed spear, the wider part of which, or that part near the shaft, is generally barbed; two feet behind this a large mass of clay encased in grass or strips of bark-like bandages is affixed round the shaft, sometimes the clay is replaced by a section of hardwood tree of great weight. The whole thing, with shaft and blade, measures some seven or eight feet in length. To use this the wily natives climb up a tree that overhangs the path taken by the elephants when going down to the river or pool of water, and as the game passes under the tree the weapon is driven down into the neck, and with the heavy weight behind it the blade often penetrates to a great depth. The elephant in trying to free itself of its burden, rubs against the tree trunks and branches; this only makes matters worse for the poor brute, for the blade is being dragged to and fro, inflicting an awful wound. Eventually the beast drops from loss of blood and is speared to death.

Sometimes, however, the drop-log instead of being discharged, so to speak, by a native, is tripped by the elephant itself. This mechanism is thus described by another traveler in the Congo, Cuthbert Christy, in his "Big Game and Pygmies."[17]

> The drop-log with its spear pointing downwards is raised vertically to a height of eighteen or twenty feet above an elephant path,

[16] London, 914, p. 183.
[17] London, 1924, pp. 83–84.

usually at a spot where it passes between two trees standing close on either side of it. The path is carefully chosen, generally one which the elephants must use to reach a plantation or group of gardens. The log is held in position by a thick forest-made creeper rope passed over a convenient branch, or a cross-bar placed for the purpose. At the end of the rope is a wooden peg which is ingeniously adjusted close to the ground between two stakes driven into the earth, or between two saplings, on one or the other side of the track. Stretched tightly across the path is a trigger-rope, one end of which is attached to the peg which keeps the whole contrivance in position, and upon the fine adjustment of which depends success. Any animal tripping over the trigger rope unhitches the peg and instantly releases the log and spear. The trap is kept unset with the log in position. On some suitable night when the elephants are raiding the crops the natives go and fix the trigger-rope, taking away at the same time some safety-catch on the peg. When the herd retires to the forest at dawn there is pretty sure to be a casualty.

Neither of the authors just quoted nor any of the other books consulted give an illustration of such an elephant trap, but I am fortunate in being able to supply this deficiency. Such a drop-log with its spear and two lianas acting as a release is admirably portrayed in a photograph made by Herbert Lang, leader of the American Museum's Congo Expedition 1906–1915. This photograph (Fig. 13) shows this effective apparatus as set up by the natives in the forest south of Medje, Congo Belge.

The tremendous blows struck by these heavily weighted spears can be realized in the following (unverified) quotation by Bland-Sutton from Stanley.—"On the road before leaving the bush, we passed a place where an elephant spear had fallen to the ground, and buried itself so deep that three men were unable to heave it up. Such a force, we argued, would have slain an elephant on the instant." This was found April 8th, 1888, on his second journey from Fort Bodo to the Albert Nyanza, shortly after reaching the Ituri River.

If such a spear penetrated the elephant's skull above the open base of the tusk, as shown in Fig. 11 from Owen, and if in the animal's struggles the beam were broken off as described above, the spear-head by gravity would descend into the open pulp cavity. Thence by growth processes it would be covered in ivory and carried forward into the body of the tusk, as is portrayed in Figs 8, 9 and 10.

The exact method by which the spear-head is transferred forward into the solid part of the tooth is admirably put by Mummery (1924, p. 231) as follows:

> The persistent growth of the great incisor tooth forming the tusks of the Elephant sometimes gives rise to remarkable conditions. Several cases have been recorded where an Elephant has been struck by a javelin or loaded spear which has penetrated the pulp at the free-growing end, and the vitality of the tissues has been so great that the death of the pulp has not followed, but the spear [-head], carried forward by the growing tooth, has been completely surrounded by the subsequently deposited ivory and has become immovably fixed in the tusk. Such a case is shown in the photograph, figure 142 [Fig. 10 herein]. The head of the javelin and a portion of the iron shaft are embedded solidly in the ivory.

It has been stated by both Bland-Sutton and Tomes that sometimes natives, stationed in trees over elephant paths, drop by hand loaded spears into the heads or backs of elephants in the hope of bringing about their deaths. This is confirmed by the ethnologist Vanden Plas in his work "Les Kuku."[18] The Kukus of the Anglo-Egyptian possessions (northeastern Congo) climb trees as noted above and by hand hurl down on the passing elephants spears much larger and heavier than those normally used in hunting.

The heads of these spears will measure 14 inches long by 2 inches wide and have

[18] In C. van Overbergh, "Collections de Monographies Ethnographiques," Bruxelles, 1910, VI, p. 164.

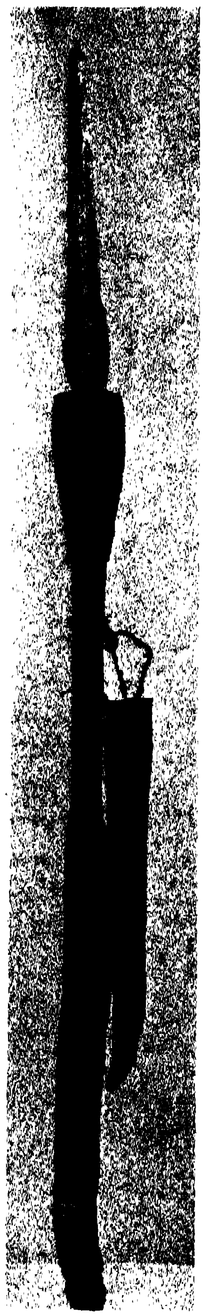


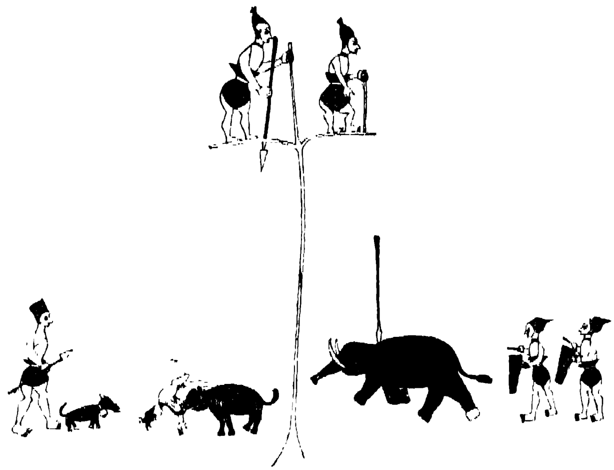
FIG. 14. A SPEAR FROM THE CONGO
FROM THE COLLECTIONS OF THE AMERICAN MUSEUM CONGO EXPEDITION, 1909–1915.

a base or haft inserted 5 inches into the bamboo shaft. These shafts are as much as 5 feet, 3 inches long. The extremity (lower?) of the shaft is wrapped in elephant hide firmly bound with lianas. This mass of skin is 15¾ inches long and 7 inches in circumference (over both hide and wood). This is presumably to add weight to the spear and to make it fall straight.

Two elephant spears similar to these were brought back from another part of the Congo by the Lang-Chapin expedition elsewhere referred to, and are now in the collections of the American Museum. I have examined these, which have long blades and heavy handles 3½ or 4 feet long, and curiously enough that part of the shaft to which the spear-head is attached has been wrapped in some sort of material and this covered over with antelope (?) skin.

One of these spears is portrayed in Fig. 14. The head of this spear is 14¾ inches long and 2 wide near the base. The handle is 42½ inches long. The enlarged and weighted lower end measures 7½ inches long by 3¼ wide. The outer covering of hide is without seam and seems to have been pulled on like a stocking. Under this is another leather covering. The grip end of the wooden shaft is covered with grass and mud and the whole closely wrapped with some liana-like material, presumably to give weight and a firmer hold for the hands. Attached is a leathern sheath to cover and protect the blade. This comes from Faradje, Belgian Congo. Dr. James H. Chapin has examined this spear and identified it as an elephant spear intended to be dropped by hand from a tree.

That these accounts are correct may be seen in Fig. 15, a native Congo pictograph from an elephant's tusk brought back by Herbert Lang, leader of the American Museum Congo Expedition of



From Lang, 1918

FIG. 15. PICTOGRAPH FROM CONGO IVORY

SHOWING HOW ELEPHANTS COME TO GRIEF FOR PLUNDERING NATIVE PLANTATIONS.—THE ELEPHANTS, FRIGHTENED BY TWO MEN BEATING DRUMS, ARE SPEARED AS THEY PASS BENEATH THE TREE. AN INFURIATED ELEPHANT CHARGES ONE OF THE MEN, WHILE THE LITTLE DOG (WHOSE WHEREABOUTS IS INDICATED BY A CLAPPER FASTENED TO HIS COLLAR) STANDS READY TO TRACK THE SCENT OF ANY ELEPHANT WHICH ESCAPES.

1909–1915, and reproduced by him in 1919 in an article "Famous Ivory Treasures of a [Mangbetu] Negro King."[19] Here this method of spearing elephants by an entirely different Congo tribe is most interestingly portrayed. It will be readily recognized that such a spear would be very effective for killing an elephant. Both figure and legend are copied from Lang.

[19] *Natural History*, vol. 18, p. 548.

HUMAN POSTURES AND THE BEGINNINGS OF SEATING FURNITURE

By Dr. WALTER HOUGH
U. S. NATIONAL MUSEUM

IN the long history of man before the periods marking important advances in his arts, there is as yet little known of his manners. Any conjecture as to his postures at times of rest must depend largely upon observations on men unconscious of civilization. Fortunately, there have survived groups of races, such as the Australians, pocketed off the main current, whose habits may be a tentative index to those of men of the archeological periods.

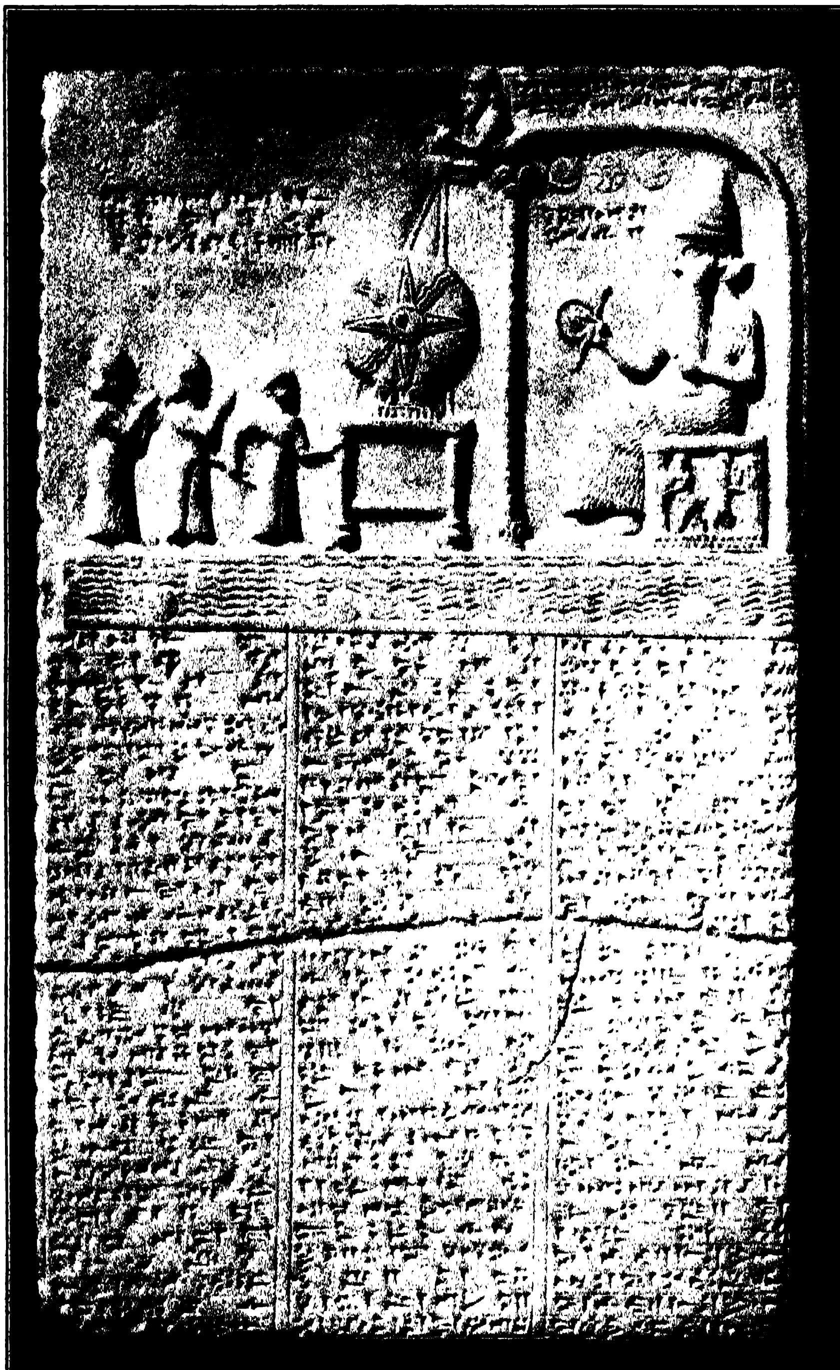
At the same time there run parallel with these data other data that grew out of physical conformations of the body after the assumption of an upright posture, that is, postures which have become functional and assumed eventually the order of instincts. The latter are only noticed here, and it is not intended to enter into the consideration of postures that have been adopted during an increased artificiality of life in various environments. These postures may be referred to housing conditions of primitive social life, on flat areas of cave floors or domiciles, to rest positions on the hunt, march or camp; or to positions required at work. These are a direct response to man's physical needs, due to his acquired sitting posture. We consider that man's natural position of rest is squatting, sitting, kneeling or lying down. A winded athlete or any one with faulty respiration assumes a bent posture and later a sitting position, but not an erect posture.

Three type postures can be recognized: squatting, which would be indicated on bad ground in any climate, practiced generally by men as a rest position, coupled with ease of going into action and also a convenient pose for certain classes of work. The second type is sitting, with legs at sides, or vertical, or extended more or less, or crossed under or crossing each other. The latter is generally woman's posture, and is indicated in warm climates on prepared, smoothed camp or floor areas under safe conditions. The third posture is kneeling, generally transitional or required in certain arts. It is sometimes a poised or mixed posture with one knee up. It evidences a reduction of height for utility and the application and control of applied force in various work, and is practiced by both men and women.

With these postures will be indicated a fixity of custom for a long period in which an artificial seat is non-existent, man keeping close to the ground or sitting on a ledge, stone, tree or other suitable article. The employment of definite artificial aids satisfying the natural need did not reveal itself until social organization became more complex.

The generality of free-moving animals maintain an alert posture under all conditions, this being broadly a necessity to survival in the "tooth and claw" organization of nature. Protective structures and tremendous proliferation relegate some animals to a low-habit grade, seen in the majority of forms below the vertebrates, except insects and in some other classes of life where external encasement substitutes for the skeleton.

It is not remarkable, then, that in the early stages of man there survives the



SEAT OF THE SUN GOD. MESOPOTAMIA. BRITISH MUSEUM.

ANCIENT GREEK THRONE CHAIR. BERLIN MUSEUM.

alert posture habits or instincts, and that these have become softened in the artificial organization of society which secures periods of ease under protection.

Of the appliances with which man ministers to his comfort we may mention especially his sleeping and seating furniture. Before these, even the essential fire steps into the background. It is not saying that to be housed a man requires fire; attention is merely called to the accommodation of the house to man's physical frame at rest and not to the matters of heating and cooking.

The house itself is not here considered, whether the act of sheltering artificially is an unconscious reaction to exterior influences that nature projects or even the consideration of the question whether the geometrics of the house represent mere physical anthropological dimensions. The within of a house is undoubtedly calculated in its various three-dimensional extensions to contain a limited number of human beings where essential movements and postures are also limited. Observations show that living in a house at certain phases of culture, say of the Bronze Age, differed greatly from that of later times.

Pointing out the greatest difference, we present the fact that in early times the house was only a portion of outdoors, home life and open-air life being in an unequal ratio. The house, as an

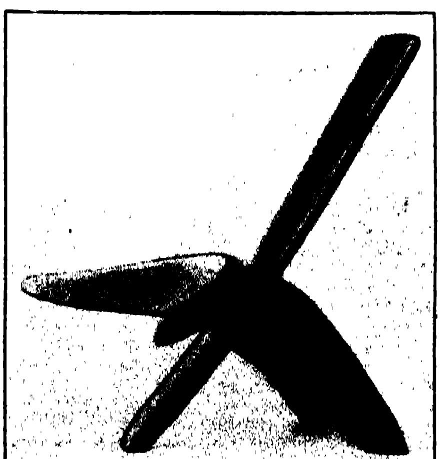
adjunct of outdoor life, was a shelter enclosing against storms and observation, for the rest periods and private affairs of family existence. Human social organization that necessitated a house for a family or a communal house had progressed far toward aggregation of habitations called hamlets, villages, towns, cities and metropoles. The house, considered as a part of outdoor life, continued into higher phases of social order and even still in the highest examples preserves some of the primitive customs.

As to the essential furniture of the early habitation, an estimate of this may be made and checked up against the furnishings of houses of the uncivilized who still remain close to the ground. At once it will be seen that rest is the prime motive. The bed or such assemblages equivalent for the purpose of interposing buffers against the hardness of the ground appears in its rudiments. The development of the bed has many inconsistencies and adaptations to climate and other regulative factors.

This primitive resting device of a "bed" has had an important bearing on the development of seating furniture, perhaps in a primary sense. There are innumerable observations of the secondary use of bed devices as a seat. It is even necessary to promulgate a tabu against the urge of highly civilized man to destroy the contours of a bed by sitting ungracefully on it.

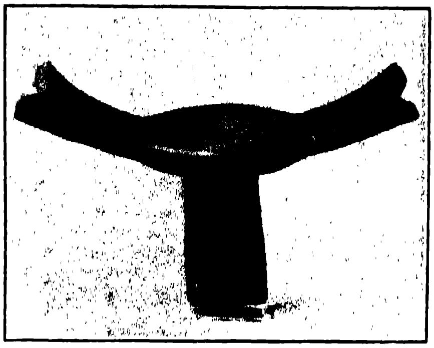
In a low state of culture described, man early learned to interpose some medium between his body and the ground, in the form of "bedding" for use at night. Materials used would be furs, grass, leaves, softened fibers of bark and suitable plants in masses, suggested still by the long line of antecedents of beds and cushions that in some areas, as in the East, solve the general problem of furniture.

In the more advanced history of house construction and planning it is found that, especially in temperate and northern environments, banquettes often form part of the structure. In such environments generally houses were partly subterranean, to put into effect the acquired knowledge that this feature was advantageous in shielding the family to some extent against both heat and cold as well as the winds, and making the dwelling more stable and safe. Upon the banquette the family sat, worked, lounged and slept. The bodily heat of



SIMPLE BACK REST SEAT. CONGO, AFRICA.

STONE SEAT WITH ARMS. MANABI, ECUADOR.



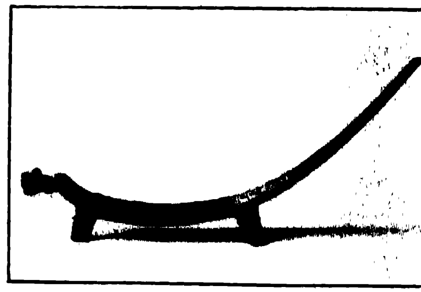
ONE-LEG STOOL. CONGO, AFRICA.

the occupants and the central fire, if maintained, would raise the temperature of the air of the house, and the banquette served also to elevate the sleepers from the cold floor into the zone of warmer air. That this first knowledge of heated air was put to practical use is unquestionable, as Eskimo examples of the high banquette show. The bank saved the sleeper also from rodents and thus served as a protection.

The banquette is the forerunner of benches and beds as house furniture, not universally, but in some environments and particular advances in culture peculiar to these environments. The line is clear, say in England, but would not apply to the ancient customs descending in the East in the use of cushions and mats which conserve the state of affairs in the time when man kept close to the ground.

CARVED WOOD SEAT. ANGOLA, AFRICA.

The Oriental habit of reclining on cushions may be traced presumably to the necessities of a pastoral life, which involve the constant moving from place to place with the herds and in general an existence in the open air, cutting down house furnishings to a low figure. This, it is presumed, was the inheritance of some nations if not all who do not possess rigid seating furniture. The vast hordes that swarmed from Asia toward the Mediterranean or warmer waters of the East were of the recumbent type. The pastoral peoples of the Near East were also of this class. The Mahommedan conquests of the seventh century spread the custom far and wide, in most cases superseding cultures like that of Egypt and Mesopotamia which had advanced to the stage of resting furniture. The Romans, breaking with Egyptian and Greek customs, adopted in the height of their luxury the so-called effete reclining postures of the East.



CURVED SEAT. TURKS ISLAND, W. I.

The earliest seats were thrones of gods and kings, examples of which have been uncovered by explorations in Mesopotamia. Among the oldest is a chair depicted in mosaic, recovered by Dr. Wooley from Ur of the Chaldees. Many examples are shown in Greek and Roman ceramics and sculpture.[1]

[1] Hough, "Ancient Seating Furniture in the Collections of the United States National Museum." Smithsonian Report, 1930, pp. 511–518 (publication 3101), Washington, 1931.

THE STORY OF THE ISOLATION OF CRYSTALLINE PEPSIN AND TRYPSIN

By Dr. JOHN H. NORTHROP

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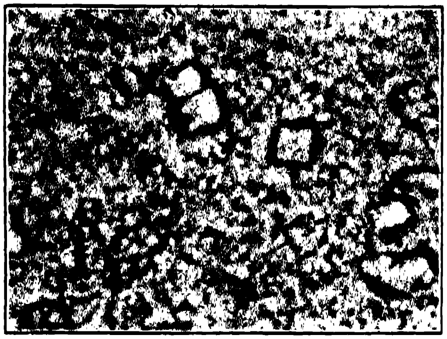
ONE of the most striking peculiarities of living things is the rapidity and precision with which the chemical changes necessary for their existence are carried on. The process of digestion is a familiar example. Proteins are split in the stomach into much smaller compounds, and this process is continued in the small intestines. The final products are precisely those needed for the nutrition of the animal and are formed from proteins with little or no evolution of heat or expenditure of energy. The process can not be duplicated in the laboratory, since chemical hydrolysis of proteins yields different products and in any case can be accomplished only by violent treatment and the expenditure of considerable energy. Similar examples of the efficiency of the reactions which take place in the animal could be multiplied indefinitely. It is now known that these specific accelerating effects which living cells exert on the reactions occurring within them and in their vicinity are due to the presence of minute amounts of some substances formed by the living cell and which have come to be known as enzymes. Without them life could not exist and yet they themselves are not living.

For centuries this property of living matter was regarded as a process of vital activity entirely outside the realm of experimental science. Evidence gradually accumulated, however, to show that the living cell was not necessary for some, at least, of these characteristic reactions; and one case after another was found in which the reaction could be made to take place without the living cell. But it was not until Buchner in 1897 discovered that fermentation of sugar could be caused by yeast extract containing no living cells that it was generally admitted that the enzyme was essential rather than the cell itself.

It had been suspected long before Buchner that the process of gastric digestion was due to the presence of some characteristic substance, and Schwann, in 1836, definitely assumed the existence of such a substance and gave it the name of "pepsin." The existence of trypsin had also been suspected early in the nineteenth century, but was not definitely assumed to exist until the time of Corvisart and of Kühne, who gave it its present name. A large number of other enzymes were then discovered by means of their characteristic reactions. It was assumed that since these reactions occurred an enzyme must exist to cause them, but there was no direct proof of the actual existence of enzymes, and, in fact, their existence as ordinary chemical compounds has been frequently questioned. The problem was analogous to that of the causative agent of an infectious disease. This agent is assumed to exist because the disease occurs, but the assumption can not be proved until the etiological factor is actually isolated.

In the meantime the chemists had found that many purely chemical reactions were accelerated by the presence of small amounts of substances which apparently took no actual part in the reaction, and Berzelius pointed out that the properties of these substances were strikingly similar to those of the active agents found in living cells. He named the general phenomenon catalysis and



CRYSTALLINE TRYPSIN (×910)

considered enzymes as a special case of catalysis.

The name "enzyme" was proposed by Kühne for these organic catalysts. In the last 50 years enzymes and enzyme reactions have been studied intensively by chemists and physiologists. The chemists have been interested primarily in the mechanism of the reaction and the physiologists in the nature of the reactions, and both chemists and physiologists have spent a great deal of time trying to isolate the enzymes themselves. Rapid progress was made in the study of the nature of the reactions caused by enzymes, but the mechanism by which they caused these reactions to take place and the nature of the enzymes themselves remained quite unknown.

Before discussing what enzymes are, it is well to review what they do. Pepsin and trypsin are typical enzymes, and the reactions which they accelerate are good examples of enzyme reactions in general. Both pepsin and trypsin cause proteins to decompose into smaller molecules but do not carry this process as far as the amino acids which are the ultimate building stones of the proteins. Along with these chemical changes there are marked changes in the physical properties of the protein. If the protein is originally insoluble it is dissolved rapidly by the enzyme, and if it is already soluble the viscosity of the solution decreases very markedly. It has often been assumed that, especially in the case of pepsin, these physical changes were not accompanied by any chemical change, but the apparent change in physical properties without accompanying chemical change is simply due, in the writer's opinion, to the fact that the chemical changes are very slight and hard to measure. According to the current theory of catalytic reactions in general, all the reactions which are observed to take place in the presence of pepsin and trypsin are already occurring, although at an extremely slow rate, and the characteristic effects of the enzymes are due to the fact that certain of the very large number of spontaneous reactions are greatly accelerated, while others are not. This peculiar property of accelerating certain reactions and not others is referred to as the specificity of the enzyme and is frequently considered another of their peculiar characteristics. In reality, however, all chemical reactions are specific and enzyme reactions do not differ qualitatively in this respect from any other chemical reaction. The time rate

CRYSTALLINE PEPSIN (×1,000)

at which these reactions occur and the effect of varying the quantity of protein or the quantity of enzyme also differ more or less from the results obtained from simpler chemical reactions, but again the difference is quantitative rather than qualitative and the anomalous results can usually be shown to be due to some complicated side reaction.

Another peculiarity of the action of these enzymes is the fact that pepsin digestion occurs much more rapidly in acid solution than in alkaline solution, while trypsin digestion occurs much more rapidly in alkaline solution than in acid solution. Proteins, when dissolved in acid, are present in the form of acid salts, and when dissolved in alkali are present in the form of alkali salts, and it is probable that trypsin acts only on the alkali salts of the proteins, while pepsin acts only on the acid salts. That this is the explanation rather than some effect of the acid or alkali on the enzymes themselves is indicated by the fact that the optimum concentration of acid for pepsin digestion is different with different proteins. The same thing is true for the optimum concentration of alkali for trypsin digestion. There is, apparently, a third class of proteolytic enzymes, like papein, which react more rapidly with the neutral protein molecule (Willstätter). Trypsin differs from pepsin in another respect in that it attacks denatured proteins, *i.e.*, proteins which have been heated, very much more rapidly than the native protein. Both enzymes possess the striking property of destroying dead cells rapidly but are not injurious to living cells. The puzzling fact that the stomach and small intestine, although composed largely of protein, are not digested, even though very rapid digestion takes place in the solution with which they are in contact, is an example of this peculiarity. A partial explanation of this difference between living and dead cells was found to be due to the fact that neither pepsin nor trypsin can enter living cells, whereas they are very rapidly absorbed by dead tissue. If living fish or worms or frogs or bacteria are placed in strong solutions of either pepsin or trypsin, nothing whatever occurs. The organisms are uninjured and live indefinitely. Any dead tissue may be dissolved, but the living cells are not injured. In the meantime none of the enzyme is taken up by the tissue of the animal, since the amount of enzyme in the solution remains perfectly constant.

If dead animal tissues are placed in the same solution, they are very rapidly digested. Before digestion occurs, measurement of the amount of enzyme in the surrounding solution shows that the enzyme is rapidly taken up by the dead tissue and disappears from the surrounding solution. When the tissue has been digested or dissolved, the enzyme is liberated again. This fact, of course, simply removes one puzzle and substitutes another, since it is now necessary to know why the enzyme should penetrate dead tissue but not living tissue. This puzzle, however, has the advantage of being a very general one and not at all restricted to enzymes, since, in general, living cells are permeable only to very few substances, while dead cells are easily permeable to almost any substance in solution.

There remains, also, the difficulty of explaining why the enzymes do not digest the surface of the cells, even though they can not enter. There is good reason to believe that the surface film of cells is not protein, and its behavior in fact is much more similar to that of an oil, so that this oil-like film is probably the mechanism which prevents living cells from being digested. When the cell dies this film is destroyed and the enzyme enters and digests the protein.

Inhibition of Trypsin and Pepsin Digestion

It was mentioned, in discussing the peculiarities of pepsin digestion, that the course of the reaction was not what would be expected from ordinary chemical theory. It has been found that the quantity of protein digested per minute decreases rapidly as the reaction proceeds. This peculiarity is caused by the inhibitory effect of products formed during digestion on the activity of the enzyme. It may be strikingly demonstrated by adding increasing quantities of these products to the protein solution before the addition of the enzyme. The more digestion products are added the slower the digestion; and in the presence of a large amount of digestion products practically no digestion occurs. The enzyme-protein system in some respects closely resembles the toxin-animal system, since the enzyme causes the formation of substances which protect the protein from the effect of the enzyme, just as the injection of toxin into an animal results in the production of antitoxin, which in turn protects the animal from the toxin. The enzyme inhibitor, however, is not nearly so powerful as some antitoxins nor is it protein.

Chemical Nature of Pepsin and Trypsin

While the behavior of enzymes has been systematically worked out in the last 40 or 50 years, very little advance has been made in the knowledge of their chemical nature so that it has frequently been assumed that they represent an unknown class of compounds. Indirect evidence has been obtained, however, that some, at any rate, are proteins. The rate at which they are destroyed by heat, for instance, is characteristic for the effect of temperature on proteins. The fact that they are adsorbed on finely divided particles is also a property of proteins more than of many other classes of compounds. Pepsin, in particular, seems to have protein-like characteristics, and in fact Pekelharing isolated an amorphous protein from gastric juice which was highly active and which he considered to be pepsin itself. He was unable, however, to show that the material was a pure substance, and the view that this protein was really the enzyme was never accepted. The writer has repeated Pekelharing's experiments several times in the last 15 years, but until recently had never been able to carry the purification any further. In the meantime Sumner reported the isolation of a crystalline protein from beans which appears to be the enzyme urease.

Nearly all attempts to isolate enzymes have been done with relatively small quantities of material and in rather dilute solution. Absorption methods have also been extensively used. If enzymes really are proteins, these are not favorable conditions for their isolation, since proteins are extremely unstable in dilute solution and are easily injured by adsorption on surfaces. The attempt to isolate pepsin was again undertaken three years ago from the point of view of protein chemistry, using only those conditions under which proteins are relatively stable, *i.e.*, concentrated solutions and low temperature. The method was based originally on that of Pekelharing. The last step in Pekelharing's preparation consisted in dialyzing a protein fraction from gastric juice against dilute acid. Under these conditions a white precipitate is formed which is a protein and which contains most of the activity. This protein sometimes appears in a somewhat granular form and under the microscope looks as though it might be trying to crystallize. Many attempts were made to crystallize the protein without success. It was noticed finally that this precipitate dissolved if the suspension were warmed to 37° C. and reappeared again upon

cooling. These are good conditions for the formation of crystals, and the experiment was repeated under varying conditions and especially with more concentrated solutions, since crystallization in general occurs more readily from concentrated than from dilute solutions. A more concentrated suspension than usual was warmed to 37° C., and this solution was allowed to cool slowly to room temperature in a beaker. The next morning it was found to contain several grams of beautifully formed crytals in the form of double, six-sided pyramids. They were tested for activity and found to be highly active and also to be protein.

The activity is about 5 times that of the most highly active commercial preparation and the quantity of protein which can be transformed by the enzyme is quite extraordinary. An ounce of the crystalline pepsin under favorable conditions would digest about 1½ tons of boiled egg in 2 hours, or would clot about 600,000 gallons of milk, while it would liquefy about 10,000 gallons of gelatin in the same time. To imitate these reactions by chemical means would require a great deal of work and violent methods, but the enzyme accomplishes it without any heat effects and, what is still more remarkable, without anything happening to itself. So far as can be determined it is present after it has done its work just as it was when the reaction was started.

Only small amounts of the crystalline material could be obtained by this method, but it was found possible to modify it and eventually to dispense with the dialysis which is the most troublesome part of the method. The crystalline protein can now be prepared from commercial pepsin preparations simply by fractionation with magnesium sulphate and then with the proper concentration of sulphuric acid. The protein crystallizes very readily, in fact much more readily than most proteins and it is easily possible to prepare half a pound in 2 days. A method was, therefore, at hand by which large quantities of crystalline protein having powerful proteolytic activity could be prepared.

The next question was whether or not this digestive power was really a property of the protein or whether it was due to the presence of more highly active molecules accompanying the protein. This question can be answered in two ways. If it can be shown that the material is a pure substance or, in other words, that it contains only one molecular species, then it follows that the protein-like properties and digestive properties must both be attributes of the same molecule. Unfortunately, it is not possible to furnish definite, positive proof of the purity of any substance. It can only be stated that so far it has been impossible to separate it into two or more substances, and this statement may be made with respect to pepsin. The composition, optical activity and digestive activity remain constant throughout 7 successive crystallizations, and this would usually be considered satisfactory proof of the purity of a substance.

As a result of these experiments it can be said that no indication was found that the material was a mixture by the usual tests. Owing to the fact that it is a protein, however, it is quite possible that the crystals are a solid solution of several related proteins. The relation between protein and activity may, however, be tested in another way by comparing the loss in activity with the destruction of the protein. If the activity were due to some other molecule associated with the protein it seems probable that conditions could be found which would decompose or change the protein molecule without affecting the activity, or *vice versa,* whereas if the activity were a property of the protein molecule itself it would be expected that anything which affected the protein

molecule would also affect the activity. It was found that this protein was denatured, that is to say, changed into an insoluble form, in very dilute alkali. This is quite unusual for a protein. A careful study of this reaction was made, therefore, and it was found that the loss in activity was just proportional to the amount of soluble protein transformed into insoluble protein when various amounts of alkali were added.

If a solution of pepsin is allowed to stand in dilute acid at 30° C. to 50° C. the protein hydrolyzes slowly so that the quantity of protein in the solution becomes less and less. Under these conditions it was found again that the decrease in activity was just proportional to the decrease in the quantity of protein present. Finally, it was found that the denatured protein formed by the action of alkali could be changed back, at least to a small extent, to the soluble form by allowing it to stand for some time after the alkali solution had been partially neutralized. The soluble protein recovered in this way has the same activity as the original protein. These experiments, therefore, show that when the protein is denatured the activity is lost and when the protein is hydrolyzed the activity is also lost, and, furthermore, that none of the products originating from the hydrolysis of the protein have any appreciable activity. They are very good evidence that the activity is really a property of the protein molecule.

There seems reason to believe, then, that pepsin (and probably urease) are proteins; but evidently, since there are many hundreds of enzymes, it can not be concluded at once that all enzymes are proteins. There is some reason to believe that trypsin is also a protein, since it has been known since the time of Kühne to be associated with the protein fraction. In fact, it had been supposed by some workers to be a nuclear protein, but Levene was able to show that this was not the case.

An attempt was made to continue the methods used by the earlier workers and to isolate a crystalline protein from pancreatic extracts. The problem turned out to be a difficult one, and a great deal of work was done before any encouraging results in the way of either a crystalline product or a product of constant activity was obtained. The most hopeful method seemed to be a combination of fractionation with acid and salt, as was done in the case of pepsin, but with trypsin it was necessary to use ammonium sulphate. A protein fraction was eventually obtained which had a constant activity and gave some indication of crystallization. The work was made difficult by the very unstable nature of the protein. This unfortunate property made it impossible to allow a solution to stand for more than a few hours, so that the usual process of crystallization, which consists in allowing a solution to concentrate or cool very slowly, could not be used. After a large number of unsuccessful attempts, Dr. Kunitz was able to secure definite, regular crystals by the very cautious addition of strong ammonium sulphate to rather concentrated solutions of the protein. The crystals are rather small and are of the cubic system. The proof that this material is a pure substance is still more difficult than in the case of pepsin, since it is more unstable. A large number of solubility experiments were carried out, but the results were not entirely satisfactory, as it was found impossible to complete the experiments quickly enough to avoid partial decomposition and corresponding loss in activity. The final solutions, therefore, always contained more or less inactive material formed during the progress of the experiments themselves. Several series of solubility measurements were carried out, nevertheless, as rapidly as possible and at 6° C. They were disappointing in that they indicated clearly that the prepara-

tion was a mixture. To confirm this result a study was made of the changes in activity when the protein is denatured, as was done with pepsin, except that in this case denaturation was carried out by heating in dilute acid. The trypsin protein when treated in this way becomes denatured and insoluble. This experiment showed clearly that the preparation, although crystalline, was undoubtedly still a mixture, since a considerable amount of the protein could be coagulated and removed from solution without decreasing the activity of the solution. As the heating was continued, however, and more and more insoluble protein was formed, it was found that the activity began to decrease about in proportion to the formation of insoluble protein. It appeared, therefore, that the original preparation contained two proteins, one of which was easily coagulated by dilute acid and carried no activity with it, while the other one was much more resistant to acid and was associated, at least, with the activity. These results furnished also a further method of purification since, by heating the crystalline material in dilute acid, about one third of the protein could be removed without loss in activity. Considerable amounts of the preparation were treated in dilute acid in this way and a second preparation obtained which was about twice as active as the first one. It crystallizes more readily than the first preparation and the crystals are similar. The purity of this material was again tested by solubility measurements and the results were more satisfactory than with the first preparation but still not really convincing, owing again to the very unstable nature of the substance. The loss in activity when a solution of this substance was heated in acid was just proportional to the amount of native protein changed to denatured.

The protein is rapidly digested by pepsin and several careful experiments were done in which the amount of trypsin protein digested by pepsin was compared with the loss in activity. They showed very clearly that digestion of the protein with pepsin resulted in the loss of a corresponding percentage of the activity, so that whenever a molecule of the protein is digested by pepsin it loses its tryptic power. There is, then, no evidence that the products resulting from the action of pepsin on trypsin have any tryptic power. The experiments were varied by allowing the preparation to digest itself in dilute alkaline solution. Under these conditions also the decrease in the protein concentration is exactly parallel to the decrease in the activity of the solution.

It was found by Mellanby and Wolley that trypsin solutions possessed the remarkable property of retaining their activity after being heated nearly to boiling for a short time in dilute acid. The solutions of crystalline trypsin may also be heated for a short time nearly to boiling without any loss in activity and, what is still more remarkable, without the formation of any denatured protein. This result is obtained only if a solution is allowed to cool before being tested for either denatured protein or activity. If the solution is tested while still hot, it is found that the protein is all denatured and, in addition, that the solution is inactive. It is possible to show, therefore, that the formation of denatured protein is accompanied by a loss in activity and, what is more significant, that the reformation of soluble, native protein from the denatured protein is accompanied by recovery of the corresponding activity. As in the case of pepsin, therefore, it is found that whenever anything is done to the protein molecule the activity is lost and that, on the other hand, when the denatured, inactive protein is changed back into soluble, native protein the activity is regained. If it be assumed that the activity is due to some special

active molecule, then it must be assumed in addition that the conditions for inactivating these hypothetical molecules must be the same for denaturing the protein molecule and also that the conditions for rendering the hypothetical molecule active again are precisely the same as those for forming native protein from the denatured protein. The behavior of proteins in general is so peculiar and characteristic that it is extremely unlikely that any other type of molecule would be affected in the same way and to the same extent so that the possibility that the activity is due to a non-protein molecular species present appears very remote. It is possible, on the other hand, that the preparation is a mixture or solid solution of several closely related proteins and that only one of these is active.

The general properties of pepsin and trypsin which have been determined by these experiments show that they are similar in many respects to hemoglobin. Their peculiar ability to digest proteins is lost as soon as any change, such as denaturation, is made in the molecule. The denaturation of hemoglobin likewise results in complete loss of its characteristic property of combining reversibly with oxygen. On the other hand, some of the properties of hemoglobin, such as its combination with carbon monoxide and its characteristic absorption spectrum, are retained by the denatured form and even to some extent by pieces of the molecule when it is hydrolyzed. In the case of pepsin and trypsin there is, at present, no indication that any of the pieces of the molecule retain their digestive power; but it is quite possible that more careful search would show more or less activity associated with one of the decomposition products. The peculiar properties of hemoglobin are known to be due to the presence in the molecule of a characteristic group which differentiates it from other proteins. It is quite possible that the enzyme proteins likewise contain a characteristic group, but so far no evidence has been found for its existence. They are, however, quite different from other known proteins in many respects and this difference must be due to some characteristic difference in chemical structure.

"TRIAL AND ERROR"

By Dr. W. L. SEVERINGHAUS
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A CAREFUL reading of the history of science shows that its real progress was subsequent to the introduction of unprejudiced experimentation. In this method, when at its best, the experimental results were obtained and appraised with an open mind. From these results basic explanations were sought and resulting hypotheses and theories proposed. Further observations disclosed that the first theories were either imperfect or entirely wrong. There often arose several theories which were in themselves contradictory, that theory being used which seemed best fitted to the particular problem in hand, while the others were, for the moment, forgotten. So it has gone on through the centuries, never arriving at the complete understanding of the real nature of things. This is the apparently discouraging process in the life work of the scientist. After long years of such a program one is tempted to exclaim "What price knowledge!"

In a public address in New York, I one time heard John Galsworthy say that the solution of every problem raised a new problem more difficult than the first. He cited as one example the "plumbing problem." It was a long and difficult job to learn how to bring to a large city plenty of fresh water and how to dispose of the sewage. But the problem was finally solved, and the result was that apartment houses and buildings 50 stories high were made possible. As a consequence, a huge population was cared for in a very limited area, which in turn resulted in a transportation problem for the subways more baffling than that of the plumbing.

A student just entering upon a rather prolonged sequence of studies in physics once stopped me after the lecture and said: "I am disappointed. I have been taking courses in the social sciences and have grown weary of having one man's guess as good as another's. I had hoped that physics had arrived at answers that were final, and then early in the sequence you confess, with not too great embarrassment, that the answers to many proposed questions are not known and that the physicists are even divided in their opinions." That is a real disappointment and it is to such disappointed minds that these few remarks are to be primarily addressed. For those who have never experienced that distress this discussion may have little interest.

Carved over the portal of one of America's greatest biological and geological laboratories, great not in cubic feet but in scientific achievement, is the age-old admonition and promise, "Speak to the earth and it shall teach you." At first that sounds very hopeful, but soon the shrinking questions arise: "Isn't Mother Earth rather large for me to speak to? And anyhow where is her ear? And what language does she understand?" One grows skeptical and says: "Earth can't teach one anything. One must sit with one's thoughts and figure things out by cold logic." It is my purpose to demonstrate that while Mother Earth may sometimes leave one cold, such unaided logic leaves one colder if one is interested in the world of events. Let us admit at the start that although by neither method may one hope to arrive at the final whole truth, yet one may ascertain which of the two is more fruitful in its by-products.

It would appear obvious that the ac-

quisition of knowledge presupposes a certain amount of interest in the world and its problems. Given the required curiosity, nature itself furnishes the laboratory and equipment for endless observation, and the discovery of a new phenomenon will always result in a peculiar kind of joy. The phenomenon may not be new to the world and yet the independent observation of it is gratifying.

Allow me to give a few very simple illustrations from my own experience. I was looking at a common variety of coleus plant on our window sill and suddenly observed that the stalks of this plant were of square cross-section, with the edges quite sharp. That seemed very remarkable and wholly inexplicable. Not that I understand why they should be round, but I certainly could not understand why they should be square. Not long afterward I was sitting by the side of a botanist at the dinner table and decided to inform him of this discovery, hastening to ask whether there were many such plants. I confess that some of the thrill of the discovery left me when he told me there were perhaps a thousand or more, and that all members of the mint family had that peculiarity. I then asked him how such growth could take place. Were the individual cells perhaps square-cornered crystals? He replied, "Now you are raising a real question about which there is much discussion."

One of my greatest pleasures out on Cape Cod consists in throwing out bread crumbs to the birds and watching their table manners. They are mostly sparrows, old and young, with the young ones continually begging their parents for bread, even after they are able to fly with ease to the ground and back to the trees again. But the parents seem to enjoy it as much as the babies, so long as there is plenty of available bread. There are always a few babies so well fed that they grow and grow until they are several times the size of their nurses. In fact, they turn out to be not sparrows at all but cowbirds. Resorting to the bird book, I find that one of the uninspiring habits of the mother cowbird is to lay her eggs in the sparrow's nest and let the unsuspecting sparrow hatch and rear the young. The conclusion is that while the sparrow may or may not be dumb, it is certainly the friend of foundlings.

One more illustration will suffice to show the gracious way Mother Earth has of teaching, if one will only speak to her. We were lying on the seashore trying to get sunburned and casually scratching around in the sand, when one member of the party cried out with considerable animation, "Oh, look at this!" It was a little greenish pod as large as one of the beans in a lima bean pod. Inside there were ten tiny but perfect replicas of shells commonly found on the shore, about the size of the folded fist. We took it along to Woods Hole and interviewed a biologist. His remarks were something like this: "That is a very nice sample and I should be pleased to take it into the class. They have not had much luck finding them this summer. It is a snail or gastropod and its name is *Busycon Caniculatum,* sometimes called 'sea whelk.' Those little shells are perhaps a month old. There are usually ten to twelve in a single pod and fifty to seventy such pods in a string. Each little shell has an animal in it. Starting as an egg it becomes a larva, which develops a shell gland and that forms a shell around the snail." I leave it to you to imagine how many conversations with Mother Earth were enjoyed before those six sentences could be placed in the book of knowledge.

These illustrations suffice to show the ease and simplicity with which one may commune with nature, but it would be misleading to leave the impression that

the serious business of modern science consists in letting Mother Earth lull us to sleep with bedtime stories.

Let us take as a more elaborate example the search for the answer to the question, "What is light?" Please note in the first place that a goal has been set and that the scratching in the sand is no longer aimless. The history of this quest shows that the thousands of years before Al Hazen and Roger Bacon may be passed over as worthless. They may have been interesting to those delighting in pure speculation for its own sake, but they got nowhere with the question itself, and the by-products of the contemplation were indeterminate. Real progress began when men began to make concrete observations on the behavior of light. Then it was found:

That ordinary sunlight could be broken up into beams of different colors in passing through a prism and that these beams could be recombined to form the original light;

That light travels more slowly through ponderable matter than through free space and that the bending of a beam of light upon entering a piece of glass is definitely related to the velocities of the light in air and in glass;

That light travels in free space with a velocity of 186,000 miles per second;

That a beam of light can be broken into two beams upon entering a clear calcite crystal and that a piece of this crystal can be so cut that one of these beams is shut off completely, while the other passes through apparently unobstructed;

That the solar spectrum is shot through with very definitely placed black lines and that these lines coincide with the bright lines from certain luminous gases;

That two beams of the same colored light can be so combined as to form darkness;

That light experiences certain influences in passing through a magnetic field and that it seems to gravitate toward the sun in passing it on its journey from a distant star to the earth;

That some substances when charged with negative electricity lose their charge when illuminated by the proper light. Nearly all these experiments have since been repeated with radio waves.

The discovery of these facts extends over a period of three hundred years and will be forever associated with such illustrious names as Newton, Huygens, Roemer, Young, Fraunhofer, Faraday, Foucault, Maxwell and Hertz. Newton and Huygens were contemporaries, both were great experimenters and both were great philosophers and logicians. Newton concluded from his observations that light consisted of discrete particles, while Huygens concluded that it was a form of wave motion. The opinion of most scientists of the day was that Newton was right because Newton said so and he was always right. Who were they that they should dispute the great Newton? A century later Thomas Young performed his famous experiments on interference of two beams of light, and the tide of opinion was forced to swing around and admit that Huygens was right after all. It was an unhealthy scientific state of mind to be so willing to say that things must be so because Newton said they were. They forgot that knowledge must come from the earth and not from Newton. However, little by little, the time came when all were firmly convinced that Huygens was right—light was not corpuscular but undulatory. The experiments could not be otherwise explained. Again the scientists became intellectually crystallized and this time in a wave mold. Every evidence from conversations with Mother Earth about light was stoutly resisted when it seemed to imply that a continuous wave-stream theory could not fit the observed facts.

During the past twenty-five years

there has been an increasing number of observations in the field of radiation that require introducing into the theory some of the characteristics of the old corpuscular or discrete particle concept, while other phases of the experiments require the undulatory or wave theory. The result is that physicists are now trying to accommodate themselves to the notion of light being broken up into discrete packages, where the packages are filled with waves. The undulatory theory has not been abandoned, but it has been greatly modified and extended until now it is believed that even the electrons and atoms themselves are undulations, although they are at the same time corpuscules. At any rate, experiments performed with the deflection of electrons and atoms by crystals yield results identical in form with those of light and x-rays. At last, you say, after three hundred years we have arrived at *The* answer, spelled with a capital T. Not so! We dare not hope that we have gotten *The* answer; we have only gotten *an* answer. We don't know enough about light to give the ultimate answer and probably never shall, for the evidence to date seems not to promise that we shall reduce the universe to a simple formula. The more experimenters work at the job the more complexities are revealed.

Perhaps you feel the picture altogether too dismal, and so it is if you have your heart set on the "ultimate." It appears that the final answer is not within our grasp, but that ours is the privilege to keep on speaking to the earth and to continue to learn both simple and complex truths. While mysticism and certain types of philosophy may discuss and hope to find the "ultimate," natural science seems to have concluded that such a goal is impossible in the world of events. A wider understanding of this basic principle would do much to remove a certain false idolatry of science in the minds of the general public to-day. There appears to be a general willingness on the part of the layman to believe that whatever modern science says is not only so but is final. Such a feeling is, to say the least, highly unscientific.

What are some of the by-products of this long and partially successful series of researches for the answer to the question, "What is light?" It would take an encyclopedia to record them. The recital of a few must suffice: we have probed into the very heart of the stars, we have felt their pulse and taken their temperature; we have probed microscopic bacteria; we have learned to generate, transmit and receive radio waves; we have seen the arrival of the talking moving pictures in color; we have achieved the transmission of pictures over the wires as well as through the air. We, like Newton, can not claim to know the full answer, but we know a great deal more than he did and have reaped the harvest that he could never even have dreamed.

The process has been a long succession of carefully planned experiments with attempts to interpret results which were sometimes as expected and sometimes quite surprising. Many times the interpretation was false, as proven by further experimental results, and the latest explanation none too lucid. But in spite of the errors the trials have resulted in enormous advances in our appreciation of nature and in our control of the forces for comfort and happiness.

Professor Ogden Rood, in an inaugural address at Troy University in 1859, told the following story which illustrates beautifully the necessity for continual experimentation in the field of science in spite of what appears to be reasonably well-established theories. About the beginning of the last century there arose a great interest in the theory of optics and the development

of optical instruments. The microscope was still rather crude, but by 1840 the English opticians had increased very considerably the available light from the object under observation by increasing the angle of aperture to 135 degrees. Their leading optician, Mr. Ross, announced that it was optically impossible to increase the angle beyond 135 degrees and that therefore no further important improvements could be looked for on the microscope. In the year 1846, Dr. Gillman, of New York, who was in possession of one of the finest French microscopes produced up to that time, was told that a back-woodsman from Canastota, a little up-state village, was anxious to examine this instrument. Dr. Gillman consented, and the man came down to see it. He looked through it, twisted it, screwed it up and down until Dr. Gillman feared his sacred microscope would be ruined, but the stranger turned around and calmly said: "I can make a better microscope than that!" "Really, sir," said the doctor in contempt, "if you can make a better instrument than the first optician of France, you ought to begin at once, for you certainly will make your fortune." The doctor repeated this story to his friends with great relish, until one morning about six months later he received a very superior instrument from Canastota. This gentleman had not only produced lens combinations far superior to any known up to that time but had also increased the angle of aperture from 135 to 178 degrees. The English opticians were all upset and much controversy followed. Ross, however, had the candor to say he was not ashamed that he had been beaten, though he was mortified that he had been surpassed by a man destitute alike of scientific friends and capital. This man was Charles A. Spencer, who founded the famous lens company which now bears his name, located in Buffalo, N. Y.

If, then, this procedure is to be accepted as the key that unlocks the doors to knowledge in the realm of natural science, is it unreasonable to hope that it will yield equally surprising returns in the realm of the social sciences and religion?

Plymouth, Massachusetts, will always remain one of the most fascinating spots in the world, the real birthplace of our American Republic. That handful of stern Puritans was prompted to make the daring experiment of establishing on this remote and hostile shore a democracy where they could enjoy their civic and religious freedom. They found the carrying out of the experiment filled with bitter and unexpected sorrows. How different were the results from the anticipations that first winter when they saw their little band withering away! One can see them sitting before their fireplaces after a day of struggle, contrasting the world of reality with the world of their dreams. But they were brave and continued the experiment with its concomitant errors. The errors that developed, such as witchcraft, were so many and so grave that short-sighted present-day crtics would seek to discount the whole of their endeavors. But how do you think the dreams of Elder Brewster and Miles Standish compare with the reality of to-day? They could not possibly have grasped the far-reaching results in religion and government that have flowed from that experiment so magnificently conceived and so courageously carried on.

As one roams along those little winding paths on that first old Burial Hill in Plymouth at the head of Leyden Street, the thoughts and emotions are very mixed. Those stones tell the story of great disappointment as well as of supreme joy in the launching of the profound undertaking. At the gateway to that celebated hill stand two churches, one the "First Trinitarian

Congregational Church" and the other the "First Unitarian Congregational Church." They stand there because a difference of opinion arose which seemed too fundamental to allow organic union between the groups. It is difficult to see just how to apply the experimental method to the solution of such questions. Perhaps the experiment is one that must be prolonged over the centuries of Christian theology in order to observe the fruits of the two points of view. Such experiments in theology, as also in government, are extremely difficult because of the great number of uncontrollable variables that enter into the observations, and they require an enormous amount of patience. But unless experimental evidence pro and con can be collected, such questions must be assigned either to the realm of pure logic or to the realm of "taste."

In making this plea for the experimental method I am not unconscious of the many instances where men have spoken to the earth with great earnestness, open-mindedness, intelligence and patience and have gone away feeling that the lesson learned was far from what had been hoped for and almost too vague to be stated. Such results are known in research laboratories as "negative." They may be of great importance at times either in closing off blind alleys for other investigators or in suggesting new avenues of approach. They are, in general, however, very disappointing to the one who launches the experiment.

The now classic illustration of the so-called "negative result" in the field of light was performed in 1886 on the Western Reserve campus and is known the world over as the Michelson-Morley-Miller experiment. This famous experiment was designed and carried out to demonstrate and measure the absolute velocity of our earth in space. The sensitivity of the apparatus seemed adequate to detect and measure the effect as called for on Newtonian principles, but the observations, even if they were not unquestionably negative, as Professor Miller believes they were not, were nevertheless not conclusively positive and not at all of the presupposed magnitude. These results lay unexplained for twenty years or more before they became the basis for one of the fundamental postulates in Einstein's theory of relativity.

Passing again to the field of government for an illustration of "negative results," allow me to present a part of a recent article in the *New York Evening Post*, written by William Lyon Phelps on Nathan Hale. After telling briefly the story of Hale's graduation from Yale, his teaching school, entering the army, coming with his regiment to New York, attempting to get much needed information for Washington by entering the British ranks as a spy, being caught and hanged at the age of twenty-one, Phelps concludes as follows:

> Whenever I think of Nathan Hale I think of a line in the poetry of Browning: "No work begun shall ever pause for death." The paradox that success may come out of failure has never been more impressively illustrated than in the life of Nathan Hale. In his supreme undertaking he completely failed. When he was led out to execution I do not think he mourned chiefly the fact that he had to die in the flower of his youth; or that he had to leave the girl to whom he was engaged. His most poignant suffering must have come from the thought that he was a failure. In the bitterness of his heart he asked himself: "What will Washington say? He will say he wished he had sent a better man, a man who might have succeeded." But in spite of his complete failure, in spite of the fact that he never dreamed of his fame surviving his ignominious death, he died bravely, with an incomparably fine farewell.
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> Now suppose Hale had succeeded; suppose he had brought back information that might have given Washington a great victory; suppose this had shortened the war; suppose Hale had become a major general; and that after the war he had become President of the United States and lived to enjoy honorable old age.

All of these successes could not begin to have to-day the inspiring effect on humanity that flows from Nathan Hale the failure.

It has not been my purpose to raise questions that are crying for solution, much less to suggest any answers to these questions, but to have laid emphasis once more on the importance of first an intelligent and alert dissatisfaction (not mere cynicism), with the *status quo;* secondly, a willingness to apply the laboratory method of solution; thirdly, a readiness to weigh and accept the results of experimentation with an open mind letting such results be the pointing hand towards further experimentation. Unless we are willing and eager to adopt such a program in science, government, education and religion, we are not only doomed to decadence but to death. We must approach with confidence new problems in social relations and character building.

WHAT CONSOLATION IN THE NEW PHYSICS?

By Professor FREDERICK S. BREED
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A PARTICULAR outburst of Thomas Carlyle has often been extolled. When he growled, "Gad, she'd better," in vigorous comment on Margaret Fuller's famous statement, "I accept the universe," he must have aroused a thrill of kinship in the heart of many a resignationist who leans back on the everlasting arms, puts his faith in the absolute, trusts the cosmos, or simply says with Mr. Mencken, "It's a great show, look and laugh."

Few can be so entertainingly and exclusively esthetic as the irrepressible Mr. Mencken. Our western civilizations today are irretrievably moralistic. They are erected on the theory of the betterment of mankind, the improvement of human relations; on the sorely harassed theory of social uplift, if you will. Even as, in these modern days, humanism denies the supernal sanctions of orthodox religion and substitutes therefor the sanctions of mundane experience, the moral problem shows no sign of abatement or a lapsing life. Religion that short-cuts the solutions of life's puzzles through superstition tends to vanish from the scene, but morals continue on.

Modern humanism is essentially amelioristic. It has faith in progress. It holds that by dint of human energy the fundamental goods of life may be enhanced. These goods are the classical trio—truth, beauty and morality. They are known by their effects—their roots by their fruits. Just as truth is a quality of a human thought, so morality is a quality of a human act. Both qualities find the test of their validity in the satisfactions of men. Morality becomes then a matter of consequences. That plan of action is right which mediates in the direction of the most satisfactory state of experience, or, to put it more objectively, contributes most to man's adjustment to reality.

Humanism is a philosophy of life. All philosophies, like all religions, must square themselves with the facts of science. They may use stones that the scientific builders reject (and there are such), but they reject at their peril stones that science uses. The philosopher does not live in a world apart; he only seems to. Though he fails to recall what he got into the bathtub for, that is only one of the embarrassing by-products of his occupation with abstractions. Philosophy is general in its outlook; sciences are particular. The function of the philosopher is the integra-

tion and interpretation of all knowledge. His speciality is "*weltanschauungs.*"

It is a favorable omen, though not unattended with dangers, when, as in these latter days, philosophers are cultivating a more intimate acquaintance with science, and scientists are weighing the effects of their findings on prevailing modes of thought. The cult of the scientist-philosopher is in the making—a cult to which science is more than a vague generalization and philosophy more than verbal technicalities. Eddington specializes on the nature of nebulous galaxies and spherical surfaces of space-time, but his lectures do not quail before the baffling problems of mental function and revealed religion. Millikan and Compton spend their days in intimate communication with electrons, quantum discharges and cosmic rays, but they step out of their scientific rôles long enough occasionally to enlighten the cohorts of religion and morals on such doctrines as libertarianism and divine immanency. On the other hand, Russell comes into the picture from the side of philosophy. He surveys the work of Compton, Millikan, Heisenberg, Schrödinger and Bohr on the internals of the atom, and then tells the world that, reduced to lowest terms, it is nothing but a series of events.

Few recent discoveries in physics or in any other science have so challenged the imagination of thoughtful persons as have those regarding the nature of the atom. And few conclusions have so ruffled the complacency of scientific thought as has the principle of indeterminacy. This principle is being interpreted as undermining the very foundation of classical physics, the law of causality. Friends of religion and morals are hailing the new theory with undisguised enthusiasm. The world now seems to be free from the chains of physical causation and man's spirit given wings. Free will comes into its own again and something akin to free spirit appears to be operating in the innermost recesses of the atom and so at the very heart of the universe.

An atom no one has yet directly observed. It is an inference. The physicist studies the effects of radiation and from the seen he builds a picture of the unseen. The picture is usually that of a mechanical model. It portrays the atom after the manner of a planetary system. A proton acts the part of a sun and electrons are the planets. The simplest atomic system is presumed to be a proton with a single electron. This is the atom of hydrogen. Atoms of other elements are made by the simple addition of electronic satellites.

The so-called principle of indeterminacy has been stated as follows: An electron may have position or it may have velocity, but it can not in any exact sense have both. This statement looks innocent enough, but it has led some writers to assert that the principle involved ranks in importance with the principle of relativity. If true, it means a denial of determinism in the sense that "the data required for a prediction of the future will include the unknowable elements of the past."

Many of those who seem competent to form judgments betray some hesitancy or reservation in committing themselves to the theory. There is quite clearly a doubt, and in some intelligent quarters a considerable doubt, as to whether the new view will be able to maintain itself in this rapidly changing region of knowledge. Eddington is rather strongly inclined to accept it. "It is a consequence of the advent of the quantum theory," he says, "that *physics is no longer pledged to a scheme of deterministic law.* Determinism has dropped out altogether in the latest formulations of theoretical physics and it is at least open to doubt whether it will ever be brought back" (1929). As late, however, as 1927 Einstein wrote: "It is only in the quantum theory that Newton's differential method becomes inadequate,

and indeed strict causality fails us. But the last word has not yet been said. May the spirit of Newton's method give us the power to restore unison between physical reality and the profoundest characteristic of Newton's teaching—strict causality.''

According to Bertrand Russell, the new theory amounts to a confession of scientific ignorance. That is, it may be a reflection of the inadequacy of measuring devices rather than an utter impossibility of measurement. Perhaps, as Schrödinger seems to suggest, an electron is not a particle but a phenomenon of wave interference, in which case there may be at one moment position without detectable velocity, at another velocity without detectable position, and yet all that goes on may be explainable in terms of wave mechanics.

In the light of the above pronouncements a degree of openmindedness is clearly justified with regard to this new theory. It would be well, however, to consider briefly the consequences of its truth and of its falsity, to recanvass some aspects of an ancient problem, still unsolved and perhaps insoluble.

Rightly or wrongly, determinism has filled the ranks of moralists with discontent. As the sciences of physics and biology and psychology have tied up the world more and more completely in causal connections, the moralist has persistently fought for a region apart where he could breathe in some measure the pure air of freedom. His suffocation has been aggravated and his alarm increased by the moral bankruptcy of those who find no room for ethics in a deterministic world. If all activity is naturally caused, including human activity, what place remains for moral responsibility? the query goes. And if an agent is not responsible for his action, what is the meaning of right and wrong?

In comparison with its alternative, the doctrine of determinism has been unduly maligned. As a matter of fact, the point of view of thoughtful leaders in social administration has been gradually shifting for some time in its direction. In criminology these leaders increasingly incline to the belief that the offender is a machine defectively constructed or out of repair. In education they inveigh less and less against the wicked aberrancy of young perverted wills, and look upon their charges in the guise of machines in need of a mechanic. The most vicious criminal becomes simply a venomous serpent with danger written in his social contacts. One does not berate the rattlesnake for his offense. One does not regard him as personally responsible. But his act is wrong, nevertheless, as judged by its consequences, and the foes of wrong react in natural manner to prevent its recurrence. Under the sway of determinism this poisonous creature may logically be executed, he may simply be incarcerated, or he may be subjected to measures of reform. Most significantly, however, reform replaces vengeance as an objective, and sympathetic insight goes hand in hand with remedial treatment according to the causal law.

This view will be charged with a degree of inconsistency. An objector may urge that this method of treatment violates the logic of determinism and invokes the freedom of the will. The reformer, it may be contended, is a *deus ex machina* surreptitiously introduced to make the system operate. This, however, seems not to be the case. The reformer is part and parcel of the system of causation in which the criminal also is enmeshed. He reacts as naturally in opposition to crime as the offender toward it. He himself is indeed a natural force for righteousness.

The moral ideal, according to this view, seems in last analysis to depend for its safety in part on the existence of atomic-structured brains that react selectively to moral qualities. How explain a positive reaction of a human organism

to right and a negative reaction to wrong? How explain the positive reaction of a lower organism to light and its negative reaction to darkness? All organic activity, according to the determinist, regardless of complexity, is an expression of natural causation. In accordance with natural causation the activity pattern may easily be modified in higher organisms. By physical and social heredity the conservators of the moral ideal are known to reproduce their kind. Educational institutions and other agencies of human welfare are recognized means to this end. But there is no guarantee that the world is safe for morality or democracy or any other social end. Evil is as real as righteousness. The devil incarnate breathes destruction in the midst of things. The spirit of noble living sits upon his neck and enjoys a triumph for the moment. But ultimately, what? One finds the determinist's answer only in terms of a courageous faith in the cosmos. In the last analysis he, as moralist, is obliged to trust the universe.

The modern program of social uplift leans on mechanism. In mechanism it not only places its reliance; with mechanism it also has a comfortable alliance. The new principle of indeterminacy, on the other hand, subjects this program to the mercy of caprice. The law of conservation of energy passes with the law of causality. The future no more grows entirely out of the past. It may now grow *ex nihilo*. The problem of creation is solved. Pure novelty leaks into the world, and the days of magic and miracle have once more returned.

Insofar as human activity is exempt from the reign of causality, insofar is it exempt from the scientific technique of modification and improvement now in vogue. What consolation, then, does the principle of indeterminacy offer to world-anxious souls? If the cosmos in its atomic recesses denies the causal law, that kind of cosmos must of course be trusted. In the mass it still is known to act lawfully except for an error inappreciably small. Insofar, however, as it is capricious, an additional unknown is introduced into the equation of life. The possibility of prediction is thereby curtailed, the strain on faith is correspondingly increased, and confidence in cosmic support is inevitably weakened.

No one has argued more brilliantly for indeterminism nor with less pretense of proof than William James. To him free will was a "cosmological theory of promise," just like the absolute or God. James anticipated the present topsy-turviness of scientific theory and its relation to our problem when he said a quarter of a century ago: "But nature may be only approximately uniform; and persons in whom knowledge of the world's past has bred pessimism (or doubts as to the world's good character, which become certainties if that character be supposed eternally fixed) may naturally welcome free-will as a *melioristic* doctrine. It holds up improvement as at least possible; whereas determinism assures us that our whole notion of possibility is born of human ignorance, and that necessity and impossibility between them rule the destinies of the world." As truly also, one may say, is retrogression a possibility under indeterminism, for novelty knows no favorites and chance is marked with supreme indifference.

The moralist, proceeding on his fundamental presupposition that nature is improvable, plies her with remedial measures. Changes occur for the better. Evils are indeed remedied. Is the achievement his or nature's? Both, of course, for man is a part of nature. With pride have saints regarded themselves as instruments of God. With no less pride may the moralist become an instrument of nature.

But he is also in some measure an in-

dependent agent. No one suspects that the oxygen atom, when assuming polygamous bonds with two atoms of hydrogen, is entirely drawn thereinto by the rest of the universe. The rest of the universe may in familiar fashion oppose or abet the union. But if the marriage is consummated, the atoms have themselves in part to blame. Causality does not bring about their union, for in the best current tradition of science causality implies no force. What does it do, then? Indeed, it does nothing. Similarly, any other law of nature. The law of gravitation does not cause a sparrow's fall. Natural laws are merely descriptive. They are as inert as a mathematical formula. The law of causality expresses the fact of customary sequence among events. B follows A. That is causality. Why B instead of C or D? Why anything at all after A? There is no answer in the principle of causality.

To discover what hydrogen does in the presence of oxygen explains in no way the doing. The event is simply found by science and recorded *post rem*. Do atoms, like the moon, shine from borrowed light? Are they mere unwinding clocks? What principle of rationality requires one to believe that energy is forever borrowed from elsewhere, or from some single pervasive source? Why not a myriad sources? The secret of that which is observed is hidden away in the elements themselves, for aught that science teaches. Thus are oxygen and hydrogen said to have certain ways of acting, certain modes of behavior. Refer to them as bonds, or affinities if you like. These are theirs, attributable, so far as known, to nothing elsewhere. And, if the simplest element conceivable reacts independently in the simplest way possible toward any other element, there is freedom of action. Freedom of action is freedom to act. It means the opportunity to act in accordance with one's nature, the opportunity to be oneself. External determination, not internal, means the denial of freedom.

Why, then, the cheers for indeterminism?

RADIO TALKS

By AUSTIN H. CLARK
U. S. NATIONAL MUSEUM

The use of every new medium for the diffusion of information necessitates the development of a more or less highly specialized technique in order that its potentialities may be utilized to the greatest advantage. The progressive advancement of the magazines and later of the modern newspapers has now been followed by the perfection of the radio as a means of imparting information to an increasingly large section of the public.

As a vehicle for the diffusion of information, other than news of immediate and pressing interest, the radio is still largely in the experimental stage, for there are as yet no generally recognized principles comparable to those governing writing for the press to which radio talks are made to conform.

One difficulty in the way of formulating and enforcing rules governing radio talks, especially talks on academic or scientific subjects, is that the personnel of the radio stations seldom feel themselves at liberty to speak with the requisite frankness to those who appear at the stations, while at the same time the speakers themselves know little or nothing about the inherent peculiarities of the radio.

Another thing is that most talks at present are simply individual talks by various speakers who reappear at the station at irregular intervals—if they are invited to reappear at all. Few of the more important stations make a specialty of talks. So there is no incentive for studying the subject in the thorough and detailed manner in which the presentation of news in the press has been studied.

But the possibility of increasing the proportion of talks in their programs is now interesting many stations, and in addition several organizations are engaged in planning series of talks which, through their appeal to the public at large, shall be of real value to the stations for which they are given.

The preparation of a radio tálk which will meet with general approval on the part of the public, please the station from which it is given, and reflect credit on the speaker, is no easy task. It involves the cooperation of at least two people, in addition to that of the censor of the station from which it is to be delivered. It demands strict adherence to a number of different limiting factors which do not apply, or at any rate do not apply with such force, to items of similar length intended for publication.

In a radio talk the opening paragraph must include something sure to interest the listener so much that he or she will continue to listen. For instance, suppose that I am giving a talk on "The Cow-bird" and I begin, "Our cow-bird, like most cuckoos, the honey-guides of Africa, some weaver-finches, some hang-nests, the rice-grackle, and a South American duck, and according to recent information one of the paradise-birds, lays its eggs in the nests of other birds which hatch these eggs and raise the young," the number of listeners will be reduced to the vanishing point long before I have reached the end of the sentence.

In the first place, the title—"The Cow-bird"—is too grimly prosaic and means nothing to most people. In the second place, the long string of wholly unfamiliar names of foreign birds would cause the mind to skid unpleasantly and finally to run off the road entirely.

But if I change the title of the talk to

"Abandoned Bird Babies" and begin "Those unfeeling mothers who leave their little babies upon the door-steps of prosperous people's houses have their counterparts among the birds," etc., I shall be able to follow it up with a very considerable amount of information, and many people will learn that there are many different kinds of parasitic birds of which our common cow-bird is a typical example.

A radio talk must be so written as to be an elaboration of the idea conveyed in the first paragraph. It must be written about a single main idea to which all the other ideas expressed are subordinate, or of which they are explanatory. A talk including several diverse ideas or sets of unrelated facts leaves little impression, and what impression it does leave is always unfavorable. A radio talk must be a closely knit unit from beginning to end, and the last paragraph must be in every way as interesting and as strong as the first so as to stimulate a desire for more talks from the same source.

The composition of a radio talk is therefore essentially the same as that of a newspaper article. But there is one very important difference. While a radio talk must be a complete unit from beginning to end, and the last paragraph must be as strong as the first, a newspaper article must be so written that the editor, if pressed for space by some unforeseen occurrence, can clip off a series of paragraphs up to about half the total number without affecting the unity of the subject-matter remaining.

The subject-matter in a radio talk must be presented in a more or less condensed form. In a lecture the subject-matter must be well diluted, for otherwise the audience will tire. In the case of a lecture the audience is only partly occupied in listening to what is being said; a considerable portion of the attention on the part of the listeners is taken up in watching the mannerisms and subconsciously appraising the personality of the speaker. The audience listening to a radio talk is to all intents and purposes blind; the visible mannerisms and the personality of the speaker are wholly eliminated, and the listeners are entirely occupied in hearing what he has to say. The result of this is that quite as much information can be conveyed in a radio talk of fifteen minutes' duration as in a lecture occupying an hour.

All radio talks should be written in such a fashion that they are suitable for subsequent publication as newspaper features or magazine articles, and also suitable for assembling in the form of pamphlets or small books which will meet with a ready sale. If a local newspaper will not consider printing any given radio talk—at least in a more or less condensed form—that talk should be dropped in the waste-basket and another written.

In any radio talk the word order is a matter of the very greatest importance. The words must be so chosen and so arranged that the sentences shall flow as smoothly as possible. Words commonly omitted in speaking and often in writing, particularly "that," "the" and "and," must always be included. In conversation facial expression supplies many missing words, while in reading there is always time and opportunity for inserting them. But the loudspeaker has no facial expression and allows no time for thought.

It is impossible to avoid the occasional use of more or less unusual and unfamiliar words. Such words should always be preceded by several familiar and preferably short words which can not be misunderstood in order to throw the unfamiliar words into relief and thereby to facilitate their comprehension.

For instance, if I should begin a sentence "Paradise-birds are confined to New Guinea and a few adjacent islands where," etc., very few would understand what I was talking about. But if I said

"Those strange birds, of which the males are dressed in varied styles of brightly colored plumes, known by the name of paradise-birds, are to be found only in that great island called New Guinea and on a few other near-by islands" quite a number of listeners might possibly become interested.

In radio talks the personal touch is always of the greatest importance. Whenever possible talks should be given by some one with a direct personal association with the subject.

Historical talks, no matter by whom they may have been written, should be read by a person related to some one directly concerned with the event or events described, or to the person whose exploits are featured. If published, such talks will appear under the name of the real author, with a mention in a footnote or elsewhere of the one by whom they were read.

Talks on the natural sciences should always be by some one personally familiar with the subject, and preferably by some one whose name has been connected with the subject in the newspapers. Definite evidence of familiarity with the subject should be given in the form of personal anecdotes or otherwise.

In introducing the personal touch the word "I" should be scrupulously avoided. There is something subtly disconcerting in hearing a loudspeaker describe itself as "I," although no one objects to its calling itself "mè." This is the reverse of that animistic principle through the operation of which, in such languages as Russian, masculine nouns referring to living beings lack the accusative case.

In historical talks all the individuals mentioned should be adorned with the halos—or the horns and cloven hoofs—which the passage of time has conferred upon them. All historians know that history is strongly tinged with mythology; but history, on the basis of the actual facts, would never be acceptable to the great bulk of the public. Belief in the superman is inherent in all of us. We know that personally we are not supermen. But we like to believe that our ancestors were, and we like to hope that some of our descendants may achieve that status.

Nothing of a controversial nature should ever be permitted to appear in any radio talk having anything to do with any form of science. The country swarms with people to whose philosophy science in any form is heretical and abhorrent, and whose chief delight is to seize upon some minor controversy, magnify and grotesquely distort it, and on the basis of the absurd result endeavor to discredit science, and learning in general, in the eyes of all who will listen to them. Such people are most numerous in the very areas where the radio is exceptionally valuable as a vehicle for general education.

Especially in the sparsely settled sections of the country the radio ghost is a factor demanding respectful consideration. In the days of our grandparents when ghosts were common it was well known that all ghosts were possessed of a most unfriendly and often vindictive nature. With the passing of the flickering candle and the oil lamp, and the coming in of the steady and brilliant illumination of the present day, ghosts have disappeared.

However, the basic psychology that made the ghosts possible we still retain. No matter how familiar it may be to us, the disembodied voice from the loudspeaker is possessed of certain ghostly attributes, or rather is capable of acquiring ghostly attributes. The radio ghost shows itself at once when gloomy or ghastly information issues from the loudspeaker. When heard from a loudspeaker information of an unpleasant nature is many times as unpleasant as the same information would have been if heard from a friend or read in a news-

paper. Proper respect for the radio ghost is essential in the preparation of radio talks. We must remember always to make radio talks as interesting, bright and cheerful as possible in order to overcome the ghostly attributes of the loudspeaker.

It must be constantly borne in mind that the voice from the loudspeaker is to a large extent dehumanized and ghostly, and every effort must be made to overcome this effect. A few speakers are able to convey sufficient personality through the voice to overcome this of themselves. But the simplest way to overcome it in a series of radio talks is by the more or less frequent introduction of dialogues.

Dialogues are always popular. Talks on distant regions popularly supposed to be wild are most effective if they are presented as dialogues between the traveler and a young lady with a voice that sounds as if she were very pretty, who asks more or less silly questions. In order to give the necessary unified effect, the entire dialogue should be written by one person. Dialogues should never be attempted without adequate rehearsal. A plain matter-of-fact dialogue is worthless. But the development of the essential "come to me" quality in the feminine, and the "here I am" quality in the masculine, voice requires practice.

After a talk has been written out to the complete satisfaction of the prospective speaker and of his friends and close associates, the easy and pleasant part of the work is over. Now comes the part which, though absolutely essential if the talk is to be a real success, is anything but agreeable.

All radio talks before delivery must be edited by some one with no knowledge of the subject-matter but thoroughly familiar with the difficult and highly specialized technique of writing for popular consumption, who will not be afraid to commit the most fearful sort of butchery if necessary.

In scientific writing a series of facts is presented, and then the conclusions drawn from those facts are given. In a radio talk, as in a newspaper article, this procedure must be almost completely reversed. It becomes almost impossible, therefore, for any one trained in science to prepare a good radio talk without assistance.

If no trained writer is available, a good plan is to read a prospective radio talk to some one with not more than a high-school education, and then find out from him or her what is the chief idea that has been conveyed—if any.

The chief idea conveyed by a radio talk to an average person is often most disconcertingly at variance with the main point of interest in the opinion of the writer. Nevertheless, painful as the process may be, the talk should be rewritten along the lines suggested by the listener. In addition to recasting the style of a radio talk and rewriting it in good radio American, the editor has certain other responsibilities.

Everything that can possibly be interpreted as advertising in any form must be eliminated from all radio talks. This includes mention of books, magazines, newspapers, merchandise of all kinds, transportation agencies, steamers, hotels, institutions supported by private donations or public funds, etc. Great care must be taken to see that this rule is rigidly upheld and inflexibly applied to every talk. The unintentional inclusion of some form of advertising is perhaps the most frequent sin committed by writers of radio talks.

After the editor has done his part, the next thing to be considered is the performance of the speaker before the microphone. The announcers will be found to have certain very definite ideas on this subject.

All radio talks must be written out in full and read from a clean manuscript. The station should be provided with a carbon copy of the manuscript well in

advance, so that if something should happen to the speaker one of the announcers may read it at the appointed time.

All radio talks must begin and end exactly on the second, if the good-will of the station is any consideration. It is as much of a crime to end a talk a few seconds too soon as it is to run over the appointed time.

It is almost needless to say that the manuscript must be read through smoothly without a hitch or break from beginning to end, and that every word must be distinctly pronounced. But the reading must not be mechanical. The voice must be conversational in quality, and must convey the impression of a lively interest in the subject-matter. But any oratorical attempts are taboo—oratory oozing from the loudspeaker is always ridiculous, as many politicians have learned.

If a word be mispronounced or omitted, no correction must be made; the talk must continue as if nothing had happened. On some people the correction of a word or of a phrase make a more lasting impression than anything else in an otherwise perfect talk.

Clearing one's throat or coughing during the delivery of a talk are absolutely unforgivable offenses which no excuses can justify. No one addicted to these diversions should ever be permitted to appear before the microphone.

By no means every one can give a radio talk as it should be given. The quality of the voice is of very great importance. What is commonly known as the New England twang is the vocal quality which is best adapted for radio speaking. The various overtones and the nasal effect, mercifully smoothed down by the loud-speaker, seem to produce a clarity found in no other type of voice. It is rather curious that a bad cold sometimes greatly improves a speaker's voice from the radio point of view.

At the radio station the speaker's attitude toward the announcer must approximate as nearly as possible that of a freshman on probation toward the president of the university, at least until the talk is over.

Perhaps the commonest fault in radio speaking is the too rapid reading of the manuscript. A talk with a duration of fourteen minutes and thirty seconds—that is, a fifteen minute talk—should consist of not more than two thousand words.

The speaker must remember that very few of his hearers are sufficiently familiar with his subject to enable them to follow him if he talks with the usual rapidity. Furthermore, two people talking face to face always to some extent read each other's lips and expression, which greatly helps in carrying on a rapid conversation.

Inexperienced speakers—indeed nearly all speakers—should be attended at the studio by a friend provided with a slip of paper bearing the word "SLOWER" in large letters which can be shown the speaker in case of necessity. Very few of those speaking for the first time can get through their talk without two or three admonitions, and some must be carefully watched on every occasion when they face the microphone. Occasionally a new speaker can control his speed, but develops a pathetic quaver in his voice. The sight of a large and conspicuous pin moving toward his arm will usually result in correcting this condition.

In any series of radio talks much depends upon the manner in which the speaker is introduced. The transition between the regular announcer at the station and a speaker from a museum or any similar organization or establishment is so abrupt that it must be in some way bridged.

The most effective means of bridging this gap is through the appointment of some suitable person whose duty it shall be to introduce every speaker in the

series. The station's announcer then simply mentions the special series of talks and introduces the museum's announcer.

The latter, speaking for sixty seconds, briefly states in popular language who the speaker is, and endeavors to explain why the talk is worth hearing. The interest attaching to the talk should be explained both in terms of the talk itself, and in terms of the special fitness of the speaker to discuss that particular subject. In other words, it must be an effective effort to "sell" the talk to people who are all primed to enjoy fifteen minutes filled with, to them, delightful jazz.

The speaker, of course, looks over the short manuscript which will be read by the museum's announcer in advance in order to make sure that the statements therein made are correct, and in order to readjust his personal feelings to the exigencies of the situation.

Speakers, especially when widely known, should always be introduced as "Mr." and never as "Doctor" or "Professor." Academic titles, such as Doctor of Philosophy, Professor of History, Curator of Mammals, etc., which of course should be mentioned in the introduction, should follow the name. Whatever social or commercial value academic titles may have within academic circles, outside of these circles they are more of a liability than an asset. They are as distasteful to captains of industry as they are to laborers.

The reason for the popular prejudice against these titles in this country (and also in England) is easy to see. To most minds they represent an attempt to create social distinctions along lines in which such distinctions are purely artificial.

In academic circles, and in the concentric rings about those circles, addressing a man as "Doctor" implies a certain respect based upon the academic significance of his profound knowledge of his particular subject—in other words, based upon the intra-academic power which he possesses by virtue of that special knowledge. In the world at large, outside of academic circles, these titles represent nothing in terms of power. They are therefore wholly meaningless, and hence are often regarded as ridiculous.

Beside the writing, editing and presentation of radio talks, there are other things to be considered in connection with them.

Arrangements may sometime be made with local newspapers to illustrate radio talks. This has been tried in various places during the past seven years, chiefly in connection with talks given from stations owned by newspapers. The pictures illustrating the talk, made up into full or half pages, are published in the issue of the paper immediately preceding the talk, and the listener looks at them while the talk is in progress.

The preparation of a really good radio talk necessitates the expenditure of a very considerable amount of time and energy. And in addition most authors undergo more or less keen mental suffering when they become aware of the utter lack of appreciation of their literary abilities, and of consideration for their feelings, on the part of the editor. So it is only fair to the author to see that the best possible use is made of his manuscript after the talk is delivered.

If the radio station from which the talk is delivered happens to be operated by a large daily paper, arrangements may often be made to print the talk in full in the first issue following its delivery. This has frequently been done. In other cases a good talk is easily placed with some newspaper syndicate or magazine.

After the delivery of a talk a number of good clear photographs suitable for reproduction by the half-tone process should be assembled for illustrations.

The talk can then be offered as a full-page feature article to newspaper syndicates, or to the larger individual papers, or sent to certain magazines.

Generally speaking, a radio talk has no great cash value, though many have been sold for good prices. On the other hand, practically all of them are worthy of publication in some form or other. In not a few cases a talk, as it was read, is not easily marketable, but certain individual items in it, if each be provided with an appropriate picture, will meet with a ready sale.

It is always interesting to trace the history of a radio talk after publication through a clipping bureau. Some talks delivered in Washington and subsequently published in full later reappeared to the extent of a page or more in the *Literary Digest*. Excerpts from these and others later came in from daily or weekly papers in India, South Africa, Australia and New Zealand. In one case an excerpt from a radio talk that was read in Washington appeared two years later as a news item in one of the Washington newspapers under a Sydney, New South Wales, date line.

The publication of a radio talk successfully overcomes that feeling of vacuous insufficiency which many experience after their first encounter with the microphone. It also serves, in practically every case, to reestablish amicable relations between the speaker and the editor. In any well-planned series of radio talks the reading of the manuscript should be regarded simply as the beginning of extensive publicity for the included subject-matter.

The effect on a new speaker of a fifteen minutes' monologue before the grimly unresponsive microphone in a sound-proof chamber where people slink about like so many nurses in an operating room is always interesting to observe. The feeling of elation experienced by many after somewhat unexpectedly surviving the ordeal renders them especially susceptible to flattery.

Every radio talk brings in letters and telephone calls from enthusiastic listeners who are quite sincere in their praise of what was said, and in their admiration for the speaker. Other letters come in from people, chiefly elderly women, who are conscious of the radio ghost lurking in the loudspeaker, and after listening to a talk relieve their feelings by writing to the speaker.

These letters must not be interpreted as representing the sentiment of any appreciable proportion of those who heard the talk. They are simply evidences of emotional reaction on the part of a very few individuals who happen to have—or wish to appear as having—much the same interests as the speaker. A dissertation on the philosophy of Anaximander delivered in Greek would result in the receipt of quite a number of enthusiastic letters from people who wished to be considered as understanding what it was all about. Letters and telephone calls are pleasant to receive, but they mean little or nothing.

Much as lepidopterous moths struggle to secure a place as near a light as possible do human moths endeavor to intrude themselves into the light of the publicity afforded by the radio. Just as soon as it becomes generally known that a series of radio talks is in preparation, pressure for place in the series from all sorts of unexpected quarters will begin to manifest itself.

This pressure for place arises from three sources—*first*, propagandists and egotists of all descriptions, grading into, *second*, cranks, still more diversified; and *third*, politicians, usually more or less closely allied with the propagandists. Politicians as a rule are quite reasonable and cause no trouble. Conversation with them, of course, must be entirely along the line of a possible loss of votes. Cranks are also easy to deal with. In

this case the usual procedure is to refer them to the manager of the station who, poor chap, is very frequently called upon to deal with such people. While it may seem unkind to send the cranks to the manager of the station, you will find that the manager himself has been responsible for the appearance of some, at least, of the propagandists in your office. In this way the account is balanced. The director of any successful series of radio talks must possess the ability to deny people a place in his series in such a way as permanently to discourage them without incurring their active hostility.

There is another phase of this subject which is of vital importance. Volunteer speakers on all possible—and many impossible—subjects appear more or less frequently at all radio stations. Many of these are recommended to the managers of the stations by influential people with no knowledge whatever of the fitness of the supplicant to discuss the subject on which he professes to be an anthority, and many are exceedingly persistent.

Every large university, or other institution of learning or culture, should be in close touch, at least informally, with the more important radio stations in its vicinity, and should at all times be ready and willing either to supply competent speakers if requested by the stations, or to pass upon the fitness of any speaker if asked to do so by the station managers. Lack of the proper cooperation between the radio stations and the local universities, museums and similar organizations has in the past resulted in the occasional appearance on radio programs of talks that reflected no credit on any one.

From what has been said above it is evident that successful radio speaking is an accomplishment that involves a curious mixture of the ability to write in modern newspaper style and the ability to address the microphone with all the enthusiasm and charm of a popular after-dinner speaker, combined with a submissive humility often conspicuously lacking in outstanding orators and writers.

Furthermore, it usually involves the cooperation of several different individuals and agencies who must work cordially together for the common good.

The development of a corps of really first-class speakers and the organization of the necessary assistance for each is now under way in various sections of the country, and at the present rate it will not be long before the radio becomes as powerful a factor in our social system as are the newspapers to-day.

SCIENCE SERVICE RADIO TALKS

PRESENTED OVER THE COLUMBIA BROADCASTING SYSTEM

THE WISDOM OF LIVING THINGS

By Professor EDWIN G. CONKLIN

PRINCETON UNIVERSITY

EX-PRESIDENT COOLIDGE is said to have used as a motto this rhyme:

> A wise old owl sat on an oak,
> The more he saw the less he spoke,
> The less he spoke the more he heard
> Why can't we be like that wise bird?

Fables in all ages have attributed to various animals wisdom, cunning, ingenuity, patience, deceit, fidelity. Such fables have an element of truth in them or they would not appeal to us. At least we can say that many animals behave as if they had these qualities. In a notable book, entitled "The Wisdom of the Body," Professor Cannon has recently emphasized the remarkable capacity of the human body to do the right thing at the right time. But all living things, plants as well as animals, do useful things and meet emergencies, often in ways that conscious wisdom can not excel. Even the simplest and smallest animals and plants avoid enemies, repair injuries, neutralize poisons, meet depressions, resist death and manage to leave offspring in the most ingenious and complicated ways.

Even the microscopic cells of our own bodies meet emergencies in ways that seem intelligent and purposive. If you are practicing sun-baths you probably know how painful sunburn can be, and yet in a short time your skin becomes brown and does not burn, because the microscopic cells of the skin form pigment which protects them. Plants often protect themselves from salt spray or desert dryness by growing a thicker epidermis, just as friction or many chemicals cause our skin to thicken and become calloused, thus protecting the deeper lying parts.

Warm-blooded animals have extraordinary ability to preserve a uniform body temperature. In hot weather the skin or mouth glands pour out fluids, which by evaporation cool the body; if it is too cold, shivering and muscular activity increase the internal temperature. In winter horses grow a thicker coat of hair, bears curl up in some protected spot in their winter sleep, and if their internal temperature approaches the danger point, they wake up, exercise and even seek food to increase their temperature. Bees exposed to cold weather gather into a dormant cluster in the hive, keeping one another warm. If those at the surface get too cold they become active and burrow into the middle of the cluster; if the temperature at the center of the cluster falls to about 57° F. they all wake up, raise their temperature by muscular work, take in food and then go to sleep again.

All animals and plants have more or less ability to repair injuries. Many plants can be cut up into fragments and each piece will retain the power of producing a whole plant. Many worms can grow new heads or bodies when these are cut off; salamanders and lizards can grow new tails or legs, and all living things have the power of healing wounds, which is by no means a simple matter.

Even more remarkable is the capacity of many animals for neutralizing poisons. If minimal doses of serpent venom are injected into animals they form an

antivenin which neutralizes the poison, and a peculiar antivenin is formed for each kind of venom. Thus guinea-pigs native to South America may be made immune to the venom of cobras from India, though never before in all their past history have they had any contact with each other. In a similar manner, bacterial poisons of disease germs are neutralized by the formation of different kinds of antibodies or antidotes. The violent toxin formed by diphtheria germs is counteracted by an antitoxin formed in the body of the victim of the disease. The same is true of the poisons formed by many other disease germs, each peculiar poison leading to the formation of its own peculiar antibody. In this way man and animals acquire immunity to many diseases, if only the poison does not act too quickly to permit its antidote to be formed. Artificial protection may be had by using the antitoxins formed in the bodies of other animals, but no chemist has ever yet been able to synthesize these chemical substances in his laboratory.

Consider further the chemical and physical processes of digestion, assimilation, respiration, excretion; of enzymes, vitamins and hormones which have such profound effects on health, growth and development. How have lowly plants and animals learned the secrets of such subtle chemical and physical processes that intelligent man has only just now come to the place where he can appreciate the great importance of these, but in most cases can not yet artificially duplicate them?

Most of these cases of unconscious wisdom on the part of living things are in the nature of useful responses to contingencies which may or may not arise. They occur only in response to a present need; they are individually acquired fitnesses.

Another large class of fitnesses are inherited. They develop not to meet a present need but for future use. For example, think of the fitness of the eye for seeing and of the ear for hearing, although in higher animals both are developed in the absence of light and sound. Consider the fitness of the nervous system for receiving and transmitting stimuli; of the organs of digestion, circulation, respiration, excretion for their particular functions; the fitness of muscles for movement, of the skeleton for support, of the various glands for forming necessary secretions. All these and hundreds of other adaptations are inherited in anticipation of future use, although they may later be perfected by use. Other inherited structures fit animals and plants for some particular place in nature, such as the fitness of fish for life in water, of birds for flying, of moles for burrowing. Man has only recently conquered the air, but many insects, reptiles and birds did this millions of years before man appeared, and they are even now teaching us skill and efficiency in flying.

Some of the most extraordinary fitnesses are found in the interrelations of organisms with one another. All the principal methods of offense and defense known to man have been in use by animals for many millions of years. Animal armor, horns, tusks, swords and arrows; armored ships and land tanks; tear gas, camouflage and "playing 'possum," indicate how little man has invented that is entirely new in principle, and the failures as well as the successes of these animal experiments in offense and defense should be of value to the human race at this particular time.

Flowers flaunt their colors, spread their odors and secrete their nectars, not to please themselves or man but to attract insects that carry pollen from flower to flower, and thus bring about cross-fertilization. The phenomena of sex attraction, ranging all the way from cells to psychology, are among the most marvelous of all fitnesses. Consider the

remarkable structures and functions of the sex cells, their chromosomes and the methods of their division, segregation and recombination, upon which all the phenomena of heredity depend. Could the wisdom of man have invented anything more perfect or wonderful?

Finally, the infernal ingenuity of many parasites in holding up, entering, robbing and torturing their victims could not be excelled by human gangsters or mythical devils. Think of the malaria parasite that is transported from victim to victim by the high-powered mosquito, of the many transformations that it undergoes to enable it to get from the stomach of the mosquito to the salivary glands, where it lies in wait for the chance to get through the skin and into the blood of the victim that the poor mosquito bites. Hundreds of other similar cases of devilish ingenuity may shake our confidence in the universal beneficence, but not in the apparent wisdom of living things.

This bare recital of certain classes of organic fitnesses or adaptations gives no adequate account of the extraordinary extent and delicacy of such adjustments. Indeed, all life is, as Herbert Spencer said, continual adjustment of internal to external conditions. Of course plants and animals and human beings sometimes make mistakes; they are not always wise, but on the whole if they are given sufficient time they find the right answer to all their problems, or they cease to exist.

II

How have such fitnesses been produced? This is the greatest problem of life and evolution. Formerly it was generally believed that each and all of them were caused by supernatural design. But the fact that one design conflicts with another, that the fitness of a parasite is matched by a counteracting fitness of its victim would rather indicate that both devilish and angelic designers were concerned. Furthermore, the innumerable ways in which plants and animals meet emergencies would seem to be no more supernatural than our own behavior under similar circumstances. Few, if any, scientists now maintain the supernatural creation, either of adaptations or of species.

Another type of explanation that is favored by some scientists and more philosophers is that all living things have some form of unconscious will, intelligence or wisdom that causes them to do the right thing at the right time. But such an explanation does not make plain the cause. It proposes a cause that is as inexplicable as the fitness itself; it substitutes a god within the mechanism for one outside it. It may be true in whole or in part, but it solves the problem only by shifting it to another field which is much more difficult of scientific examination.

Finally there is the solution proposed by Charles Darwin, namely, the elimination of the unfit and the survival of the fit. If all organisms vary in relative fitness and if those that are less fit are eliminated, while the more fit survive, there will be a continual drive toward fitness. There is no doubt that this is true and that this elimination of the unfit is much more extensive in germ cells and embryos, which we do not see, than in adults. This simple principle of Darwinism or natural selection does explain, as nothing else does, inherited adaptations of all kinds, though, of course, it does not explain the origin of the useful variations which are selected.

But classical Darwinism does not explain individually acquired adaptations where useful responses are made by animals and plants to conditions and crises which they never experienced before, such as acquired immunity to many strange poisons and venoms, regeneration of the lens of the eye of a newt after its extirpation, though this particular injury never could have occurred in

nature and the many other beneficial responses which organisms make to conditions which neither they nor their ancestors ever experienced before. In such cases there is no elimination of unfit individuals; the same animal or plant continues to survive and gradually acquires the ability to make the useful response. In many cases we know that this is done by a process of trial and error and finally trial and success. In short, all sorts of things are tried and, if they do not meet the situation, they are eliminated until finally something is tried that succeeds. This is an extension of the elimination of the unfit from persons to reactions and it does offer a formal explanation of all kinds of fitness, whether inherited or acquired.

Even intelligence and purpose in animals and man are explicable in the same way. In the development of behavior all kinds of actions and ideas are sorted by trial and error. Those that fail to give satisfaction are eliminated; those that succeed are retained. Whether it be cats learning to open a box, or man learning to solve problems, useful responses always have as their beginning a more or less rapid elimination of unsatisfactory ones. Human intelligence and purpose are the highest type of adaptation, and therefore all adaptations appear to us intelligent and purposive.

Here, then, is a mechanism for explaining the biological wisdom of plants and animals and man. But this solution of the problem is not complete, for it is based upon the unexplained fact that all living things are differentially sensitive, that is, they have the ability to distinguish between satisfactory and unsatisfactory conditions and can avoid the latter and select the former. This capacity of distinguishing between the satisfactory and the unsatisfactory, the useful and the useless, must be regarded as a fundamental property of living things, which can not at present be reduced to simpler terms. Thus we endow life at the start with the very properties which we seek to explain, namely, the capacity to distinguish and select, which are the beginnings of wisdom in all living things.

PUBLIC HEALTH PROGRESS

By H. S. CUMMING, M.D., D.Sc.
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WITHIN the memory of many of us our race has passed through an epoch-making period, unequaled in the annals of history. In its beginning little more was known of the cause, mode of spread and means of prevention of disease than in the early days of history. Synthetic chemistry was unborn. In applied physics the electric light and telephone were curiosities. In transportation the first electric train was used. In sociology there was but the first awakening of the public consciousness of the duty and necessity of community effort and of the close interdependence of the different classes of society. We have eaten largely of the fruit of the tree of knowledge. And into this great period came the world war and its immediate aftermath, the destruction of old landmarks in politics, in faith, apparently in all things that were.

The fever of war was apparently diverted into other fields of activity. The war itself had brought about the recognition of the necessity of group action in production, transportation and health, no less than in military movements; and, indeed, there was for the first time a consciousness of the depen-

dence of military success upon concerted action by the civilian population. Large sums of money and large powers were given for the purpose of improving the health and welfare of non-combatants.

Largely as the result of this increased consciousness of the importance of the public health movement having been awakened in the mass of our population, there has been a constantly broadening interest in the whole field. Not only has this been true among those elements interested in the humanitarian side, but, perhaps more important, industry and finance have been made aware of the vital significance of mental and physical well-being, not only to the individual but also to themselves and to the government. Leaders in industry and finance have had brought to them the enormous dividends from true research by competent personnel. During the same period, many countries have had an unprecedented era of prosperity for the masses and the accumulation of great fortunes by individuals and corporations.

As a result of recent discoveries in the sciences in their application to public health, and no less as a consequence of the realization of the interdependence of individuals and even of nations, that "none of us liveth to himself, and no man dieth to himself," that the strength of a people depends upon the moral, mental and physical health of its individuals, there has come a realization that the public health is influenced by environment, heredity, industry, economics, morality, education. The insanitary dwelling, the malaria stream, the diseased or idiot parent, the hazards of dust life, knowledge of diseases and how to or poisons, the living wage, temperate avoid them, all come within the sphere of the present public health movement.

Nor is there justification for the artificial division of medical science into preventive and curative medicine. The object of public health work is to prevent illness and pain and premature death. The interests of the people as represented by government are equally affected by helpless individuals, whether made so by heart disease, rheumatism, general paralysis of the insane, or by smallpox, plague or infantile paralysis. The research worker in the laboratory, the health officer in the field, and the surgeon or physician at the bedside are all directly or indirectly, consciously or unconsciously, public servants working for the public good. The ideal for which we aim is the application of every available means for the prevention of disease or injury and the provision of suitable treatment for all sick or injured. The problem is how this ideal may be attained with the greatest good to the common weal. The solution is not to be found by mathematical formulae, nor ecumenical council; it will differ in some phases in different states and cities, indeed, in each community.

The history of the control of typhoid fever which has been accomplished in the United States within the past 30 or 35 years is a splendid example of the effect of public health work. This control of typhoid fever was accomplished by the cooperation of all the health agencies of the country—federal, state and local. Typhoid fever, which formerly took an annual toll of more than 35 of each 100,000 persons in the population of the United States, is now responsible for the death of about 5 persons per 100,000 each year.

Diphtheria is one of the communicable diseases of which we know the cause and mode of transmission and for which we now possess a specific preventive, the toxoid or toxin-antitoxin mixture, and a curative agent of great potency, the antitoxin. We also have a reliable test, called the Schick test, which indicates whether or not a given individual is susceptible to the disease. The death rate from diphtheria has responded quickly to the medical discoveries of the

past few years. The use of diphtheria antitoxin gradually increased from 1894 to 1905. In the 5 years from 1906 to 1910 the diphtheria death rate in the registration cities was 24 per cent. less than the rate for the 5 years from 1901 to 1905. In 28 American cities for which the rates have been computed, the decline has been from about 116 per 100,000 in 1890 to 5.5 per 100,000 in 1930. This extraordinary achievement in public health will probably stimulate campaigns for the better control of other communicable diseases.

Studies within the past few years, which incidentally were made by officers of the Public Health Service, have shown that pellagra is a disease caused by improper diet and that the prevention and cure of the disease lie in the eating of a well-balanced diet. The identification of the human species of hookworm as the cause of a wide-spread anemia has resulted in a notable diminution of the preys of this disease.

Fifty years ago tuberculosis caused about 320 deaths annually in every 100,000 population. To-day tuberculosis causes less than one fourth of this number of deaths per 100,000. While the reduction of the death rate from tuberculosis has been undoubtedly due in part to natural causes, it is probable that much of the reduction has been the result of public health activities. Among the specific measures that have contributed to this result are improved and more accurate methods of diagnosis, the pasteurization of milk, the abolition of the common drinking cup and other utensils used in common, the inspection of meat products and improved housing.

Recent studies have developed a serum which is believed to be of considerable value in the treatment of scarlet fever. A test called the Dick test—named for the doctor who devised it—is useful for determining whether a given individual is susceptible to scarlet fever. It is believed by public health officers that this test will be of material value in the control of scarlet fever.

The first whole-time county health unit was established in the United States in Yakima County, Washington, in 1911. Five hundred and fifty-one counties in the United States in 1931 were provided with local health service under whole-time officers. During the past 15 years the Public Health Service has undertaken a program of cooperative demonstrations in rural health work from which have come many sanitary and economic profits to the communities and an impetus for the development of whole-time county health service.

It is the consensus of opinion of public health workers that the most important developments of the future relating to public health lie in the growth and strengthening of local health departments or local health units whose functions are not only to bring about improvements through education, demonstration and enforcement of local health requirements, but also to insure their maintenance as well. With the development of the local health unit, whose personnel devote full time to their duties, it becomes possible almost immediately to expand the work into a general public health program, so that the activities are not confined to sanitation alone but also include the control of the acute communicable diseases, tuberculosis work, venereal disease prevention, malaria control, school hygiene, infant and maternity hygiene, and other special activities that are required by the conditions in the particular locality served by the local health department. This plan of work has proved uniformly successful, and public health authorities generally are in accord with the opinion that the extension of efficient whole-time service throughout the United States affords the best and most effective method yet devised for bringing to the men, women and children of this country the benefits of public health knowledge and its potential application.

WILL THERE BE AN AGE OF SOCIAL INVENTION?

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Two hundred years ago the question might have been asked if there was a future for mechanical invention; then probably no one saw a great field ahead for new mechanisms. At one time, even, in the history of the United States patent office its director proposed its closing on the ground that all the inventions possible had been made. But the field for mechanical invention proved wide, and for that matter probably is still boundless. Edison took out over 1,300 patents, which means that he saw at least over 1,300 mechanical situations that might be improved. The field of mechanical invention has been and will remain wide, for imagination plus irritability goes far. Scarcely a physical situation exists anywhere that is not a challenge to ingenuity for improvement. As people become discriminating, the number of mechanical situations that get on their nerves increases. The response is—better cars, better heating, better highways, better elevators, better footwear, better typewriters.

Just as there has been a field for mechanical invention, so is there a field for social invention? Just as invention flowed out of perception of mechanical deficiency, so will invention flow from perception of deficiency in social relations? Just as a mechanical way was invented by which the farmer escaped the discomfort of cutting grain by hand, so, for example, will a social way be invented to dispose of the operation of cars by drunken drivers? Just as a way has been found for keeping the physical bodies of flies from getting into our soup, so some day shall a social invention, analogous to a fly screen, protect us from "drives"? No end of social invention, perhaps, once the attitude of attack on long-suffered nuisances and unpleasant time-honored ways is avowed.

But in contrast with social invention, mechanical invention has achieved prestige. People who clung to antiquated social concepts loosened up in favor of, say, fly screens. The astonishing assertiveness of the early steam engine somehow captivated the crude senses of the times and won for Watt a hearing that Mrs. Sanger has not yet secured. Many mechanical inventions, such as windmills, tractors and wrist watches, have psychologically been toys for adults and as such have had an entrée denied to Clarence Darrow in Tennessee. Eventually the public was won over to the idea of mechanical progress, having reformed entirely of its throwing of its Roger Bacons into prison or of guffawing crudely at its Fords and Langleys. Resistance to mechanical improvements as such has reached the vanishing point. The descendants of a stock that fought the use of umbrellas as impious and resisted the use of steel plows as poisonous to the soil now stand in line to see the new models of sixes and eights, and tell the hardware clerk where this tool and that device might be improved.

The mechanical progress concept was "sold" relatively early to the general public. The "talking point" in mechanical contrivances is now that of a new feature; while the "talking point" of a social relation is that of an old feature. Actual social invention is miles behind mechanical advance.

With social invention miles in the rear, what chance is there that it will ever catch up? May we look for two centuries of social invention as striking as

the mechanical progress of the two centuries next last past? Are we reaching a stage where we shall no longer, as has been done within living memory, throw into jail persons of socially inventive type? Shall we soon cease to line the fences, after a manner of speaking, to roar and simianize over the faults of new mechanisms of the social grain field and highway? Shall we soon see the day when the social inventor is not hurried towards the Siberia of disgraced joblessness, or breathless from flight from the guardians of free speech in our cities? In fine, shall we soon reach the state of tolerance for social invention that was reached for mechanical invention as the industrial revolution proceeded?

Some there may be who would deny the possibility that in number and utility social inventions can ever parallel the mechanical inventions of the past two centuries. With any such I would disagree. I believe that for every one of the great mechanical inventions there is the possibility of an equally ingenious and great social invention, and that for every one of Mr. Edison's 1,300 inventions there is possible an invention of the social type for the betterment of social relations and affairs. Bear in mind that social invention is still penalized, and that to cultivate a sense of conquest rather than to submit in patience is still unorthodox and revolutionary. With the shackles off social invention there would be no good reason to suppose that inventiveness would be less fertile for social progress than mechanical invention has been for mechanical advance. We have never yet hit our stride in social invention; never fulfilled the conditions, which are: a cultivated perception of undesirable conditions—a problem consciousness—and a sanctioned attack by logical imagination.

A writer[1] gives this list of some of the great inventions of the industrial revolution:

[1] Stuart Chase, in "Men and Machines."

Reverberatory furnace
Galvanic battery
Paper-making machine
Screw propeller
First commercially successful steamboat
Stethoscope
Milling-machine
Water turbine
Electromagnet
Locomotive perfected
Dynamo
Reaper
Electric telegraph
Revolver
Electric motor
Electrotype
Photography
Steam hammer
Turret-lathe
Sewing machine
Rotary press
Electric locomotive
Machine gun
Bessemer steel
Dynamite
Electric steel furnace
Telephone
Gas engine (four cycle)
Phonograph
Incandescent lamp
Steam turbine
Linotype
First safety bicycle
Aluminum process
Kodak
Trolley car
Recording adding machine
Motion picture machine
By-product coke oven
X-rays
Radioactivity
Wireless telegraphy (high frequency)
Airplane
Diesel engine
High-speed steel
Airship
Tungsten filament light
Television

Good wine needs no bush, and these great inventions need no broadcast. They with a host of others have made over the mechanical aspects of human existence. They are part of the record of human affairs. Can any such list be essentially duplicated by social inventions of the future?

Social invention will affect laws, regulations, constitutions, government, the distribution of wealth, administrative facilities, education, mental hygiene, economics, finance, penology, employment, international relations, courts. It will develop better techniques and connote vastly more intelligent operations on the social plane.

To state coming social inventions were to invent out of hand. Not much more can be attempted than to point to social disharmonies which in the nature of things should inspire the social inventor; and as to discover need is the beginning of invention it must be that none of us to-day can be capable even of indicating adequately the range of the objectives that will engage the energies of the Edisons of social invention of the future.

The spell of custom is so strong that we but faintly perceive the rectifications that might be made. We little dream of the gamut of laudable change possible in human relations. To-day we are in social outlook like the child born with a visual defect who assumes that distorted vision is normal. Thus there are those who say that war is inevitable because of the nature of human nature, and who in saying this are like those who knew that a boat could not be made to buck the current of the Hudson. In fact, the whole outlook toward social change and betterment strongly resembles the stodgy defiance of mechanical science centuries ago. Hence we know little of what lies in the sphere of social invention. But even with the low visibility of the field it is possible to point out a few objectives of social inventions which should compare not insignificantly with the major inventions of the industrial revolution.

Below are given some catchwords of social invention, these terms serving merely to focus attention on aspects of current affairs from which ingenuity might make a running start with prospect of superseding older practice, introducing refinements of design, or of projecting the larger engines and leverages of social reconstitution. The terms given will mean much or little according to the imagination of the reader. Thus, rotation of occupation might be conceived as alternating the rôles of sedentary bookkeeper and of traveling salesman month by month, or of scheduling rotations that would involve recurrent geographical change on the part of whole sections of population. The term is given, bare, and its connotation, reader, is left to you.

Over against, then, the mechanical inventions of the galvanic battery, paper-making machine, screw propeller, stethoscope, steam hammer, Diesel engine, et cetera, are social inventions relative to:

Tax system
Jury trial
Wearing apparel
League of nations
Traveling libraries
Accident prevention
Capitalistic system
Medicine
Graft
Legal service
Weights and measures
Value of the dollar
War
Minorities
International language
Distribution of wealth
Noise
Health
Motivation of production
Disarmament
Idle time
Worry
Personal insulation
Duplication
Advertising
Tariff
Cities
Wild life
Jobs
Discovery of law breakers
Regulation of production to need
Moral code
Fundamentalism
Law schools
New wants
International trade
Alumni
Crime prevention
Poverty
Political platforms
Racial accord
Court procedure
The work of assessors
Investment
Waste of metals
Overcrowded professions
The "funnies"
Rackets
Simple life
Pedestrianism
Liquor control
Form of government
Red tape
Automatic referenda
Judgment test for voters
Education
Rumor damper and lie sterilizer
Conservatism
Rotation of occupation
Travel
Community buying and use
History

Along with inventions of which the above tangential terms are but obscurely suggestive, there should be a social invention to prevent interference with the work of social invention, interference by which the uninformed may harass and bedevil the man of original mind. In mechanical invention we have reached a stage where it would simply be malicious mischief to break up the model or smash the shop of a man working on a new mechanical device. And while the trick of buying mechanical inventions and burying them is not unknown, it is not regarded with favor by impartial critics. But on the whole the mechanical inventor goes ahead freely whether in Tennessee or elsewhere, with no legislature to bother him, no pulpit to rail, no policeman as mentor. Such freedom should the social inventor have, or be

cramped in style. Unfortunately, the person with socially inventive ideas may now find himself as the early scientists and mechanical inventors found themselves—much disliked. All that needs to be changed, and with change would issue a flood of ingenuity from which, by a selective process, would come the big and little machines of social advance. The social inventor, otherwise thinker, or "radical," should be given a chance comparable to that enjoyed by the esteemed James Watt but denied the estimable Roger Bacon. We are now old in mechanics but primitives in social invention.

By this time the reader is perhaps experiencing a growing sense of difference between mechanical and social invention, and is becoming disposed to question the whole analogy. He sees that mechanical inventions concern things, while social invention involves people; but at a stage the two are alike—the stage of subjective creation. It is true that as soon as a mechanical invention is put to work, people are immediately and surely affected, and perhaps in large numbers. It will furthermore be observed that whereas the mechanical inventor has freedom of experimentation, the social inventor has no such freedom; he even finds that to style a political step experimental is to stigmatize it; experimentation has a status for mechanical invention, and quite another for social invention. Social invention is moreover denied an immediacy of fruition, unlike the mechanical, in that so many, especially voters, must be won over to the new thing before it can be set in motion under the laws. Inertia and ignorance in tracts of the public mind have to be overcome by the social innovation, while it is no bar to the initiation of mechanical improvements that the far-flung electorate is unready for change. The few who are at first interested in a new machine may choose to use it, which they are at liberty to do, and without taking a popular vote on the principles of its construction.

Admitting, even parading, the differences between mechanical and social invention, yet one may insist on certain likenesses. The act of invention is the same in either case; the man who thinks out an economy of municipal administration or a basic plan like that of Henry George is an inventor, in class with "inventors." He has envisaged a difficulty and mentally surmounted it, through creative imagination.

As to need of social inventions—new ways, techniques, procedures, laws, arrangements, provisions and planning in education, justice, professions, economics, trade and world affairs, the social inventor is exigently required. The mechanical inventor has given us too many hats; the social inventor has not given us too many techniques and aids for social ends. The mechanical inventor has given us Chicago, and the lack of the social inventor has given Chicago its city government. The mechanical inventor gave New York City the Empire State Building, and the lack of social ingenuity leaves the city to Tammany. The mechanical inventors give us bombing planes, while Cro-Magnon politicians still chip flints.

Objection may still be raised that the perfection of social and political institutions will involve a degree of social intelligence beyond the possible. If political and social development require any material change in the level of native intelligence, then of course Utopianism is a dream. But does it? It might as well have been argued, prior to the many inventions of the machine age, that human intelligence would fail under the new burden. What happened was that millions learned about machines, which carried the machine age forward some distance, and that the foolproofing of machines carried the machine age forward yet farther. The machine has edu-

cated millions in the ways of machines; the automobile age has educated incredible millions to drive at locomotive speed to the tune of seconds and inches on railless roads.

Social inventions will educate their users, as the secret ballot has educated voters. A degree of foolproofing will also be necessary—the making of techniques easy for those who are always simple and for others who are simple in streaks, as able people usually are.

The egregious waste, hostility, vain running about and febrile pantomime, characteristic of the existing world disorder and economic anarchism, are comparable to the supine helplessness of man in his physical world but a few centuries ago, which has given way to confidence, sureness, conquest and research staffs associated with manufacturing establishments. The possibilities of social invention are as great as were the mechanical possibilities that lay before the early inventors of machines. The same vaulting intelligence is required for social invention as for invention in any field. Merely adaptation is required to effect on the social plane as large a transformation as was effected on the mechanical level by the science and invention of the past two hundred years.

SCIENTIFIC EXHIBITS AND THEIR PLANNING

By ROBERT P. SHAW
NEW YORK MUSEUM OF SCIENCE AND INDUSTRY

WITH the advancement of scientific knowledge and its far-reaching applications, people are becoming more "science minded" and interested in the underlying principles of the development and operating of the many facilities and conveniences placed at their disposal. A few decades ago a knowledge of history, art and literature constituted a liberal education. To-day an understanding of science is included in such a classification. With this increasing tendency of public interest in science and its applications, there has grown a need for popular science demonstrations and exhibits. In order for such exhibits to be effective in demonstrating to the public the growth and development of the various forms of pure and applied science, together with their utilization and social and economic results, a number of factors must be taken into consideration.

Various types of appeal should be emphasized in any exhibition of science. Important among these is the appeal of the exhibits to the familiarity of the visitor with things he has already seen or with which he comes in contact during his daily life. It would be rather difficult for the average visitor to become very interested in some new scientific principle unless he could connect it with some practical application or something with which he is familiar. Important also is the appeal to the spirit of curiosity, both undirected and directed, as of a boy wanting to see all about television. Spectacular exhibits provide an appeal to the spirit of wonderment, exciting the imagination and arousing interest in the accompanying educational information. It is often possible to put over a rather technical idea by the use of a mysterious exhibit involving the same principle. There is the appeal to artistic sense which may include not only artistically designed or arranged exhibits or groupings, but also exhibits which are impressive because of the neatness or simplicity with which they operate.

Exhibits should, whenever possible, be dynamic rather than static. This is im-

portant, not only because of the stronger appeal to the visitor, but also because the whole spirit and subject-matter of science are dynamic and not static. Although the greater part of the exhibits should be presented in dynamic form, operating automatically or at the will of the visitor, they should be so planned as not to require an undue amount of attention for maintenance or demonstration. The scale of the exhibits and their arrangements should be such as to avoid an undue congestion of visitors around the dynamic exhibits. The exhibits should be chosen to attract people in all walks of life and of diversified interests. There should be exhibits for the more informed, as well as for those with less scientific background. As the main object of scientific exhibits is educational, truth should never be sacrificed in the interests of showmanship. Simple and striking ways can often be found for demonstrating principles which at first appeared too abstruse for possible presentation. There are some subjects

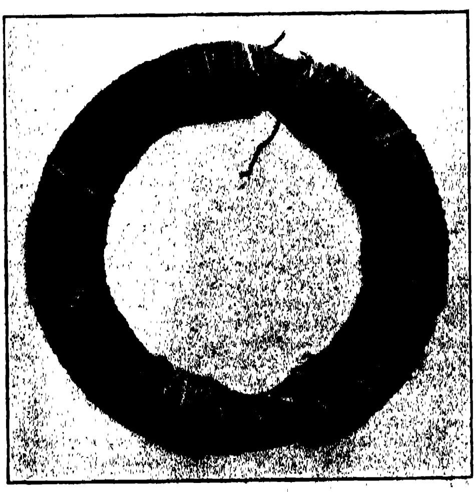


FIG. 1. HISTORIC RING OF SOFT IRON, WOUND WITH SEPARATE COILS OF COPPER WIRE CONNECTED TO BATTERY AND GALVANOMETER RESPECTIVELY. USED BY FARADAY IN HIS FIRST SUCCESSFUL EXPERIMENT IN ELECTROMAGNETIC INDUCTION.

FIG. 2. FARADAY'S "GREAT" ELECTROMAGNET.

WITH THIS HE MADE SOME OF HIS GREATEST DISCOVERIES, SUCH AS THE PRODUCTION OF ELECTRIC CURRENT BY THE ROTATION OF A COPPER DISC BETWEEN THE POLES OF A MAGNET; ALSO HIS DISCOVERY OF THE ROTATION OF THE PLANE OF POLARIZATION OF A RAY OF LIGHT, AND THE MAGNETIC AND DIAMAGNETIC PROPERTIES OF MATTER.

which can not be very intelligible to the average man, but which nevertheless are so important that they must not be entirely omitted.

Having considered a few of the aspects of scientific exhibits, the first step in developing an exhibition is to fix upon some sort of a general plan. Either a chronological development or some logical arrangement of the subject-matter, or a combination of both, may be used. In any case, there are serious objections to forced routings of visitors or allowing them complete freedom to wander at will through the exhibits. In order to meet these difficulties, it is advisable to group these exhibits into small units, with the most striking exhibit of the unit serving as the key exhibit. These units in turn are grouped

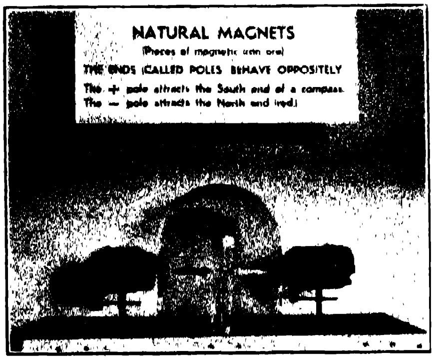


FIG. 3. PIECES OF MAGNETIC IRON ORE MAINTAINED IN ROTATION ABOUT VERTICAL AXES. THE COMPASS NEEDLE PLACED BETWEEN THEM INDICATES THE MANNER IN WHICH THE MAGNETIC FIELD CHANGES AS THE NATURAL MAGNETS ROTATE

into a larger unit or section, with the most striking exhibit serving as the key exhibit of the section. Continuing the same procedure, a number of sections are grouped into a division having its key exhibit. Thus, a visitor sees the most striking features of the divisions, sections and units in turn, and, if sufficiently interested, can examine the details of a unit without interfering with the main flow of visitors. Such a plan of flexible routings and key exhibits provides main and secondary lanes of travel for the visitors, depending upon the interest in certain exhibits or groups of exhibits. Another advantage of this plan is found in its flexibility to fit almost any type of architectural arrangement.

An exhibition of science and its applications may be well compared to a story, with the sections of the exhibit corresponding to the chapters, and the units of the exhibits to the paragraphs. By looking over the key exhibits, one sees the index of the chapters and gets a summary of the most important points.

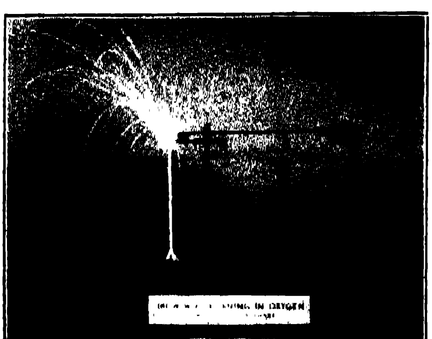


FIG. 4. THE CHEMICAL UNION OF IRON AND OXYGEN IS ILLUSTRATED BY A RATHER FINE IRON WIRE FED CONTINUOUSLY INTO A STREAM OF OXYGEN SUPPLIED BY A TANK UNDERNEATH THE TABLE.

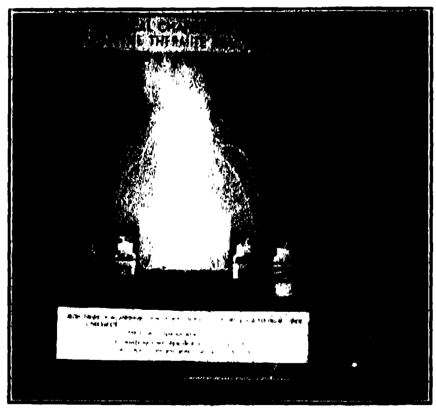


FIG. 5. DOUBLE DECOMPOSITION IS ILLUSTRATED BY HEATING IRON OXIDE AND ALUMINUM, THUS REDUCING THE IRON AND OXIDIZING ALUMINUM. THE MOLTEN IRON POURS THROUGH A HOLE IN THE BOTTOM OF THE CUPEL INTO A VESSEL OF WATER UNDERNEATH.

As in the story, there should be a connecting thread running through all exhibits. Each exhibit to be most effective should answer satisfactorily the question, "Does it advance the theme or plot one step further?"

A properly balanced exhibition should consist of four types of exhibits: (1) Static exhibits, (2) continuously operating exhibits, (3) exhibits operated by the visitors, (4) exhibits demonstrated by attendants. There are no fixed proportions which can be used for these types of exhibits, as they vary with the nature of the subject, the expense involved in construction and operation

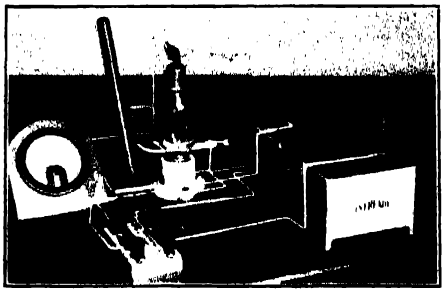


FIG. 6. AN EDISON EXPERIMENT.
WHEN EDISON WAS EXPERIMENTING TO PREVENT HIS LAMPS FROM DEPOSITING CARBON ON THE GLASS, HE PLACED A METAL PLATE NEAR THE FILAMENT AND DISCOVERED THAT A CURRENT OF ELECTRICITY FLOWS FROM THE HOT FILAMENT TO THE PLATE. THIS APPARATUS DUPLICATES THIS GREAT DISCOVERY THAT EVENTUALLY LED TO FLEMING'S VALVE, THE BEGINNING OF PRESENT DAY RADIO TUBES.

and with the scope and character of the exhibition.

The first type, static exhibits, generally is primarily historical in character. Fitting examples of this type are Faraday's ring and electromagnet shown in Figs. 1 and 2. These particular exhibits are very necessary in an exhibit of electrotechnology, for out of the simple experiments which Faraday performed with these and other pieces of apparatus have grown the science of electrical engineering and the great electrical industry as we know it to-day.

The continuously operating type of exhibit is very effective in drawing the attention of large groups of people and arousing their curiosity and interest. Such exhibits, to be most striking, should be made quite sizable and of a spectacular design. They should be placed in very prominent locations and should be made as dramatic as possible, with proper illumination and other effects. Ideal examples of this type are the three scientific exhibits shown in Figs. 3, 4 and 5. These, together with many other scientific demonstrations, have been developed by the Department of Exhibits of the Century of Progress International Exposition, Chicago, 1933.

The visitor operated type of exhibits is very suitable in demonstrating scientific principles and their applications to the visitors individually. In order to be most effective, they should present the idea as simply as possible and they should be made to operate without complicated controls and with the least amount of effort by the visitor. Two examples of this type are shown in Figs. 6 and 7.

The fourth type of exhibits requiring demonstration is the most spectacular. These, however, are rather limited in exhibitions of science from the standpoint of expense for operators. Accordingly, they should be restricted to those things which need attendant operation to make spectacular or for safety requirements. At the Annual Radio Show held last fall in New York, the New York Museum of Science and Industry gave periodic demonstrations with a large static machine and high frequency generator which proved very interesting and instructive to many thousands of visitors.

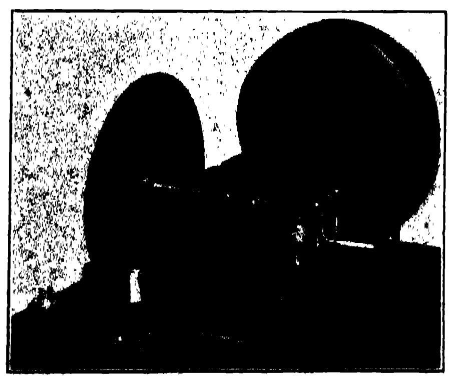
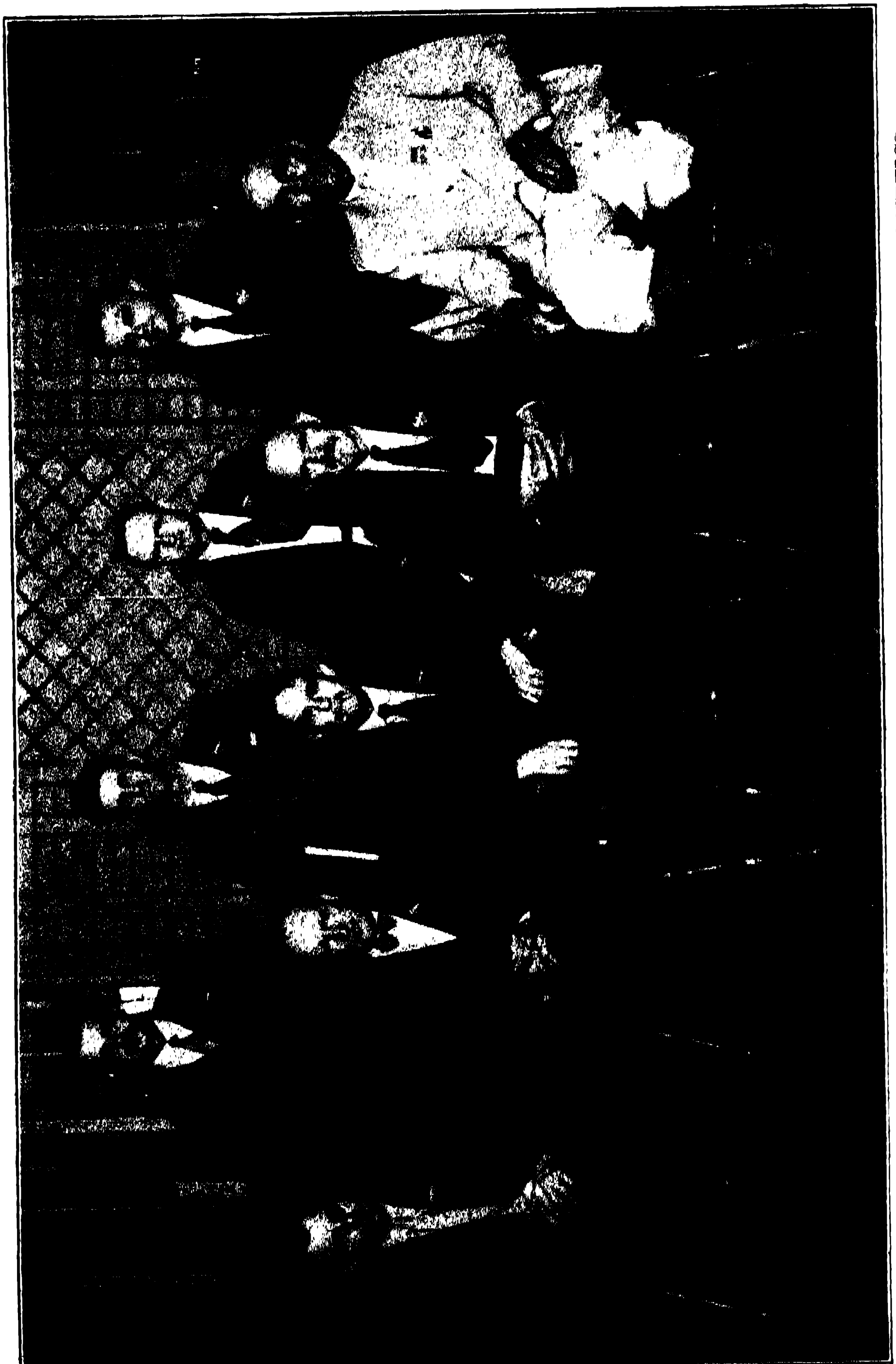


FIG. 7. PRINCIPLE OF TALKING PICTURES.
WHEN LIGHT PASSES THROUGH THE SOUND TRACK ON MOTION PICTURE FILM, WHICH IS REPLACED BY THE HOLES IN THE ROTATING DISC OF THIS APPARATUS, IT VARIES IN BRILLIANCY ACCORDING TO THE VARIATIONS OF THE SOUND TRACK. THE LIGHT IS FOCUSED ON A PHOTOELECTRIC CELL WHICH CHANGES THE LIGHT VARIATIONS TO VARIATIONS IN A WEAK ELECTRIC CURRENT. THE AMPLIFIER STRENGTHENS THIS CURRENT SO THAT IT CAN OPERATE THE LOUD SPEAKER WHICH PRODUCES SOUND WAVES.



THE EXECUTIVE COMMITTEE OF THE SIXTH INTERNATIONAL CONGRESS OF GENETICS

C. C. LITTLE L. C. DUNN D. F. JONES H. DEMEREC

R. C. COOK E. M. EAST T. H. MORGAN C. B. DAVENPORT R. A. EMERSON

THE PROGRESS OF SCIENCE

THE GENETICS CONGRESS AT CORNELL UNIVERSITY

THE Sixth International Congress of Genetics met from August 24 to August 31, inclusive, at Ithaca, New York. Approximately 550 members registered. These, with the accompanying members of their families, brought the total attendance at the congress to about 800. The foreign delegation was, in spite of the world-wide economic stringency, representative and highly satisfactory. The leaders of the foreign delegates designated formally by their respective governments were as follows:

Belgium: M. le Professor L. Frateur and M. le Professor R. Vandedries. *Chile:* Señor Don Manuel Elgueta y Guerrin. *Denmark:* Professor Dr. Ojvind Winge. *Finland:* Professor Harry Federley. *France:* M. le Professor A. Vandel. *Great Britain:* Professor R. Ruggles Gates, Ph.D., F.R.S., and Professor F. A. E. Crew, D.Sc., Ph.D. *Italy:* Professor Alessandro Ghigi, Professor Cesare Artom, Professor Fabio Frassetto, and Professor Corrado Gini. *Norway:* Professor Dr. Otto Lous Mohr. *Spain:* Señor Don Antonio de Zulueta y Escolano.

Beginning on August 25 the mornings were devoted to invitation meetings, at which the following topics were treated:

GENERAL SESSIONS

"Mendelism in Man."
"Inheritance of Educability."
"The Use of Mosaics in the Study of the Developmental Effects of Genes."
"The Present Status of Maize Genetics."

MUTATIONS

"On the Potency of Mutant Genes and Wild-type Allelomorphs."
"Mutations of the Gene in Different Directions."
"The Genetic Nature of Induced Mutations in Plants."
"Further Studies on the Nature and Causes of Gene Mutations."

THE INTERRELATIONS OF CYTOLOGY AND GENETICS

"The Interrelations of the Genotype and the Karyotype and Their Bearing upon Some Genetic Problems."
"The Cytological Basis for Crossing-over."
"Neuere Ergebnisse über die Genetik und Zytologie des Crossing-over."
"The Nature of Sex Chromosomes."

SPECIES HYBRIDS

"The Species Problem in Datura."
"Konjugation der artfremden Chromosomen."

CONTRIBUTIONS OF GENETICS TO THE THEORY OF ORGANIC EVOLUTION

"Genetik der geographischen Variation."
"The Process of Evolution in Cultivated Plants."
"The Evolutionary Modification of Genetic Phenomena."
"Can Evolution be Explained in Terms of at Present Known Genetic Causes?"
"The rôles of Mutation, Cross-breeding, Inbreeding and Selections in Evolution."

Among the most important features of the congress was the series of exhibits. This was divided into many sections, the chief of which were the live plant exhibit, under the supervision of Dr. R. A. Emerson, and the laboratory exhibits. Dr. M. Demerec, as chairman of the exhibits sub-committee of the council, set a new standard of completeness and effectiveness in the preparation of material. It was the unanimous opinion of those in attendance that the graphic representation of the most recent advances in experimental genetics was both sensational and of the greatest scientific interest. The enormous spread in varieties of material successfully utilized to investigate the different genetic problems bears impressive witness to the progress made during the past three decades.

This fact was also brought out in the interesting and challenging presidential address delivered to a large audience on the evening of August 25 by Dr. Thomas Hunt Morgan. At this session the greetings of Cornell University were most happily conveyed to the delegates by Provost A. R. Mann. The response for the delegates was delivered by Dr. Richard Goldschmidt, of the Kaiser-Wilhelm Institut, who spoke with great wit and suitability.

The afternoons, beginning on August 27, were taken up by a series of sectional meetings at which a total of over 200 papers were delivered. The sections may be enumerated as follows: General Genetics 2, Cytology 3, Animal Genetics 1, Human Genetics 1, Method of Technique 1, Genetics and Phytopathology 1, Plant Genetics 1, Chromosome Structure and Crossing-over 1, Genetics of Species Hybrids 1, Drosophila 1, Problems relating to Sex and Fertility 1, Genetics and Pathology 1, Fruit and Vegetable Breeding.

The last named section was held at Geneva under the auspices of the New York Agricultural Experiment Station. At this session a full day's program was offered. The address of welcome was delivered by Director U. P. Hedrick. The station offered a dinner and entertainment for the visiting delegates.

The program of the congress was so arranged as to allow opportunity for informal meetings in the evening of groups with a common interest. Meetings to discuss sire valuation, corn genetics, mouse genetics, human heredity, poultry linkage and gene problems were held.

During the week there were two plenary sessions of the congress. At the first of these, three committees were appointed as follows:

Committee on Resolutions: H. Federley, *chairman*, R. R. Gates, C. L. Huskins, A. F. Shull, Curt Stern, N. Vavilov, R. Vandendries, A. de Zulueta.

Committee on Greetings to Absent Colleagues: G. H. Shull, *chairman*, C. Gini, O. Winge.

Committee on Nomination of Permanent International Committee: T. H. Morgan, *chairman*, K. Bonnevie, F. A. E. Crew, G. P. Frets, A. Ghigi, H. Nachtsheim.

Besides a complete and interesting program for visiting ladies there were many informal social events. These began with a dinner in New York City at the Hotel Waldorf on the evening of August 23. At this dinner the visiting foreign delegates were the guests of the Carnegie Endowment for International Peace. The speakers were Dr. Thomas Darlington, representing the City of New York, T. H. Morgan, C. B. Davenport, J. B. S. Haldane, Kristine Bonnevie, R. Goldschmidt and N. I. Vavilov. Greetings were read from E. B. Wilson, who was absent on account of illness. At Ithaca, an informal reception, at which the reception line consisted of Provost A. R. Mann and the members of the executive council of the congress, was held on the first evening of the congress. On the third day a picnic at Taughannock Falls State Park was attended by approximately 800. Indians from the nearby reservation entertained the group by tribal dances. Group singing was also a part of the program. On Sunday, August 28, many of the members went to Niagara Falls on an all-day excursion. For those who remained at Ithaca an organ recital was offered by D. H. Jones, organist of the Westminster Choir School. Excursions to Watkins Glen State Park and to Enfield Glen State Park completed a varied and attractive program. At the close of the congress a number of the delegates were guided on a trip to several New England institutions, while others scattered to visit in Canada and the Middle West.

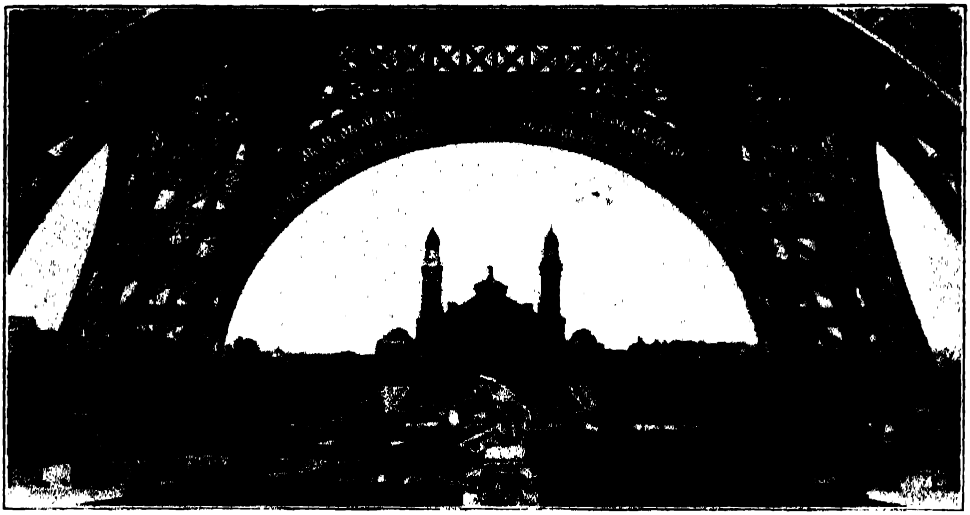
C. C. Little

THE INTERNATIONAL ELECTRICAL CONGRESS AT PARIS

FRANCE has for centuries been one of the exponent and champion nations for world science, as well as for art and literature, the herald of the imaginative spirit. Except during the calamitous world war, hardly a year has passed, since 1800, without seeing at least one scientific congress assemble in Paris. Her International Electrical Congress of 1932 (July) was but the latest of a notable series of similar Paris electrical congresses held in 1881, 1889 and 1900, each of which was convened in conjunction with a world's fair, or "Exposition universelle." This congress of 1932 was actually one year behind its schedule; because it had been intended for 1931, as a jubilee or semicentennial commemoration of its famous predecessor—the Paris International Electrical Congress of 1881; but so many scientific world events occurred elsewhere in 1931 that this congress had to be postponed until 1932. Pressure on the calendar will sometimes distort a semicentennial period into a lapse of fifty years plus one. These two Paris congresses of 1881 and 1932, being in historical apposition, may be designated as the Memorial and Jubilee congresses, respectively.

As is generally admitted, the main purpose of an international scientific congress is to invite a number of papers or "reports," perhaps a year in advance, from well-known specialists in various countries, on subjects of general interest, and to assemble the writers with a suitably large audience, for the reading and discussion of the same. These papers and discussions, subsequently collected and printed, establish a historical record of the state of that science and its applications, at the date of the symposium. A valuable by-product of such a congress comes, however, from the mutual interest and stimulus of personal contacts between workers in the same field of knowledge and research. The participants receive a renewed incentive, as well as an invigorating pleasure, in meeting and in exchanging views upon matters of mutual concern.

THE CITY OF PARIS



THE TROCADERO
AS SEEN THROUGH THE BASE OF THE EIFFEL TOWER.

The spirits of enterprise and of mutual veneration for the overworld are quickened by the associated mental effort.

At the Jubilee Congress, about 240 papers were presented, already printed in French, from representatives of some thirty nations. They had been received in several languages; but those not written in French were translated into that language by the secretariat. The discussions were likewise offered in several languages; but were all finally collected in French for the proceedings. It is expected that these proceedings, comprising both papers and discussions, will be distributed before the end of this year, in complete sets of fourteen or fifteen volumes, containing, in the aggregate, about eight thousand pages of text. Since the papers ranged in topic from the quintessence of modern electrical theory to perfections of technological detail, these sets of proceedings will constitute an electrical milestone for the first third of this century, of great theoretical, practical and historical interest.

The work of the congress was divided into thirteen sections. Of these, three or four dealt with basic electromagnetic science, and the remainder with electrical applications. During the week occupied by the sessions, several sections were ordinarily at work simultaneously, in the same building.

In 1881, at the date of the Memorial Congress, the applications of electricity were virtually limited to electroplating on metal, telegraphy by wire and arc lighting. Wire telephony was then only in an incipient stage, and incandescent electric lighting had just commenced on a small but very promising scale. The great American inventor, Edison, had produced his first successful incandescent lamp in 1879, by indomitable courage and persistence. He was exhibiting a group of them at the Paris Exposition of 1881, together with what was at that time a very large Edison dynamo-electric generator. The electric switch, now so familiar in most households, for controlling all sorts of domestic appliances, was then rarely seen, except in scientific laboratories and in telegraph offices. Electric traction, electric motor driving, x-rays and radio-communication did not exist; so that many more applications had to be dealt with at the jubilee meet-

ing than at the memorial gathering. In 1881, the subjects discussed were essentially scientific, professional and remote from public attention. In 1932, owing to the wide-spread use of electricity in recent decades, the discussions, although still scientific, come much nearer to every man's door.

The outstanding contribution of the 1881 congress was the international establishment of certain electrical units of measure, which have since been universally adopted, and have even been incorporated into the legislative enactments of most countries. A few of them, like the volt and the ampere, are almost household words. The full list of 1881 contains five practical electrical units: the ohm, ampere, volt, coulomb and farad, named, respectively after pioneer electrical researchers in Germany, France, Italy (Volta), France and England (Faraday). All these units, being based on the meter and gram of the international metric system, are simple and decimal in their use. It is generally admitted that the rapid extension of electric utilities in all countries since 1881 is partly attributable to the simplicity and universality of these decimally connected units. Indeed, it may be said that the Jubilee Congress of 1932 bears testimony, in many ways, to the scientific foundations adopted and laid down at the Memorial Congress, and especially in regard to the methods of electrical measurement and computation internationally adopted in 1881.

A change of some importance seems to have come into the philosophy of electromagnetics, between the dates of the Memorial and Jubilee Congresses, to judge by their respective literatures. In 1881, it would appear that mechanics and dynamics—*i.e.*, the properties of moving matter, as based on experiment —were regarded as fundamental sciences. Efforts were made at that time to link the conceptions of observed electric and magnetic phenomena with those of dynamics, in a subordinate way. In more recent decades, however, the discoveries of the electrical constitution of atoms, the doctrine of relativity and the doctrine of the equivalence between matter and energy have tended to displace dynamics from its central conceptual position and to replace it by electromagnetics. This change of thought does not alter any of the statements of the physical phenomena; but only the perspective of their conceptual relations. It seems likely that the next fifty years will also witness some interesting philosophical changes of view-point in electrophysics.

Out of the hundreds of members attending the Jubilee Congress, one, and apparently only one (in the German delegation), had also officially attended the Memorial Congress 51 years before. He was naturally the recipient of many congratulations.

The congress unanimously elected as its president Dr. Paul Janet, member of the Institute of France and director of the École Supérieure d'Electricité at Paris.

Beautiful weather aided hospitable Parisian hosts to make the visit memorable socially as well as scientifically.

ARTHUR E. KENNELLY

THE DENVER MEETING OF THE AMERICAN CHEMICAL SOCIETY

THE eighty-fourth national meeting of the American Chemical Society was held in Denver, Colorado, from August 21 to August 26. It was very well attended by chemists and their families from every part of the United States and from at least one foreign country, China being represented by Dr. P. N. Woo, of Shanghai. There was a total of 916 officially registered members and guests, a surprisingly large number in view of the distance of Denver from the center

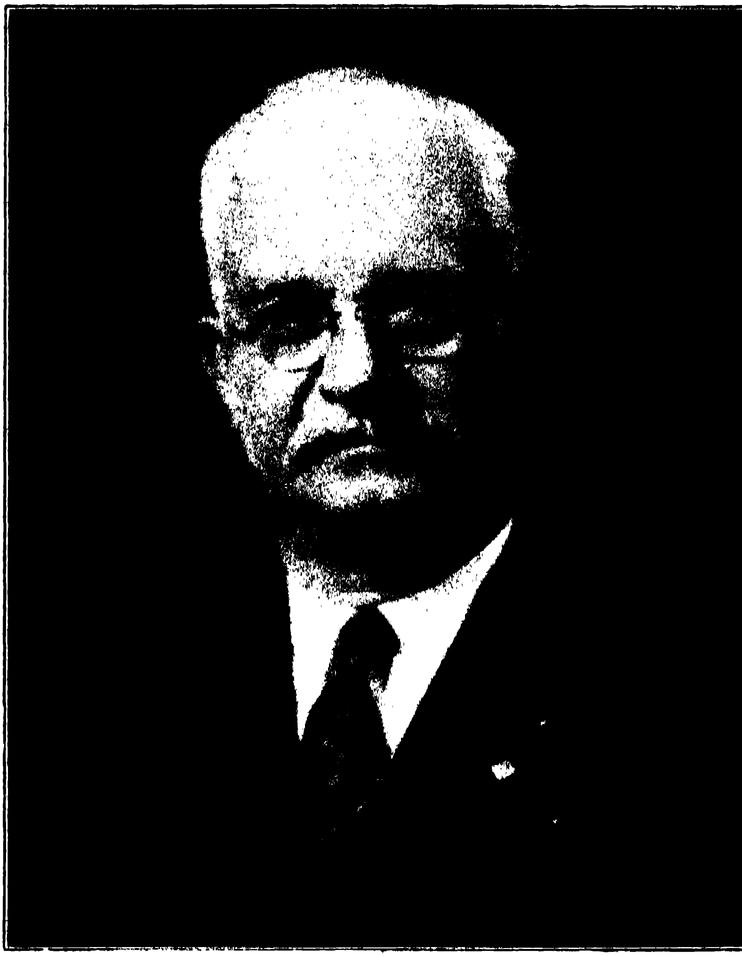
PROFESSOR ARTHUR B. LAMB
OF HARVARD UNIVERSITY, PRESIDENT-ELECT OF THE AMERICAN CHEMICAL SOCIETY.

of population of members of the society and the times of economic stress in which the country now finds itself. Many chemists took advantage of the low railroad rates to come to Colorado for a vacation as well as to attend the convention.

The general arrangement of the program was approximately that usually followed in the society meetings, with the council meeting on Monday morning, a general program with papers from the various divisions on Monday afternoon, and the sixteen divisional meetings then beginning on Tuesday morning.

In the deliberations of the council, the topic which was most discussed was the unemployment problem. It was reported that the percentage of unemployed in the ranks of members of the American Chemical Society is much smaller than among chemists as a whole. The desirability of doing everything possible to alleviate the general situation was recognized, but it was felt that this could be more efficiently accomplished by the various local sections than by the national society.

The usual subscription dinner and entertainment was scheduled for Mon-



DR. CHARLES L. PARSONS

day evening. This proved to be unique in at least two ways. The first of these was the presentation of a jeweled American Chemical Society emblem and a sterling silver tea service to Dr. Charles L. Parsons, in recognition of his twenty-five years of faithful and invaluable service to the society as its executive secretary. The other variation was in the entertainment which followed the dinner. In addition to the customary dancing, one half of the banquet room, which had been curtained off during the dinner, was found to be a replica of one of the famous gambling halls which flourished in Denver in the seventies. A number of professional gamblers were in charge and each guest was given a quantity of scrip with which he might try his luck at poker, roulette, chuck-a-luck and other games of chance. Prizes were awarded to those having accumulated, by fair means or foul, the largest amount of scrip at the end of a certain time.

A vacation was declared on Tuesday afternoon, and after being properly photographed, the entire group, about 1,250 in all, was loaded into cars provided by the local members and their

A MOLECULAR MODEL
OF MONOCHLORBENZENE CREATED BY PROFESSOR DONALD H. ANDREWS WHICH HE USED IN ILLUSTRATING HIS WORK.

friends. This motor cavalcade of some 400 cars then wound its way through Denver's scenic mountain parks, a distance of sixty miles, arriving in Golden, Colorado, about five o'clock. There Mr. Adolph Coors, Jr., head of the Coors Porcelain Company, entertained most royally in the form of a garden party on the spacious lawn surrounding his home. A fine dinner was served, after which the guests were allowed to choose among various types of entertainment ranging from visiting the company's porcelain factory, brewery or malted milk plant, to dancing, bridge or simply visiting with friends while listening to a splendid string orchestra. In addition to all this, each guest was presented with a souvenir in the form of a porcelain smoking set, embossed in gold with the society emblem.

To turn our attention now to the more serious side of the meeting, we find a total of nearly 300 papers presented in the various divisions. While it is perhaps difficult to pick out any one or two as the outstanding papers, taken as a whole the results of a vast amount of worth-while research were reported. Space permits the discussion of only a very few of these papers.

In the general meeting, one of the papers arousing considerable interest was the description and demonstration by Dr. Donald H. Andrews of his molecular models. These models were constructed of steel balls representing the atoms, with steel springs depicting the forces between them. On suspending these models by rubber bands and shaking them, it was found that each model vibrated markedly at three particular frequencies of shaking, and that these frequencies were more or less definitely related to the vibration frequencies of the molecules themselves as determined by their Raman spectra.

A symposium on the "Vitamin B Complex," under the auspices of the division of biological chemistry, attracted much attention. This vitamin, as brought out by Dr. H. C. Sherman, Dr. Robert C. Lewis and others, is evidently not a single substance, but includes several factors, probably at least seven in all, each of which contributes to the effects usually ascribed to Vitamin B. These various factors may be at least partially separated by their varying solubilities in alcohol, by preferential adsorption by fullers' earth and by other methods. Due to the variety of types of experimental animals used, it is not certain yet that all the factors reported are distinct entities, but it appears certain that there are more than the B and G (or B_1 and B_2) factors previously established. A number of other interesting studies of the rôles of various vitamins, as well as certain metals, in nutrition were reported. It might be mentioned in passing that Dr. C. G. King reported the isolation of Vitamin C in crystalline state and its identification as one of the hexuronic acids.

In the division of physical and inorganic chemistry, another symposium was held, "Metals" being the topic. Here the application of thermodynamics was emphasized. Dr. W. M. Latimer explained the use of ionic entropies in the

determination of electrode potentials of metals, especially those which do not readily lend themselves to the direct measurement of their potentials. Dr. C. G. Maier pointed out the use of thermodynamic data in determining optimum metallurgical conditions and also in improving present practices, while Dr. A. Wachter discussed the importance of thermodynamics in the study of solid solutions.

On Wednesday evening, a meeting open to the general public was held in the Denver Municipal Auditorium. At that time Dr. L. V. Redman, president of the society, was scheduled to give an address on "Some Economic Aspects of Research." Because of illness, he was unable to attend the convention, but Dr. Arthur B. Lamb, president-elect, read the paper which had been prepared by Dr. Redman. It emphasized the importance of continuing research during times of depression as well as of prosperity, and urged the stabilization of methods of financing research in order that it may be so maintained. Dr. Lamb also presented the Priestley Medal to Dr. Parsons for his contributions to the advancement of chemistry, and the Langmuir Prize of one thousand dollars to Dr. Oscar K. Rice for his research on "The Theory of Unimolecular Gas Reactions."

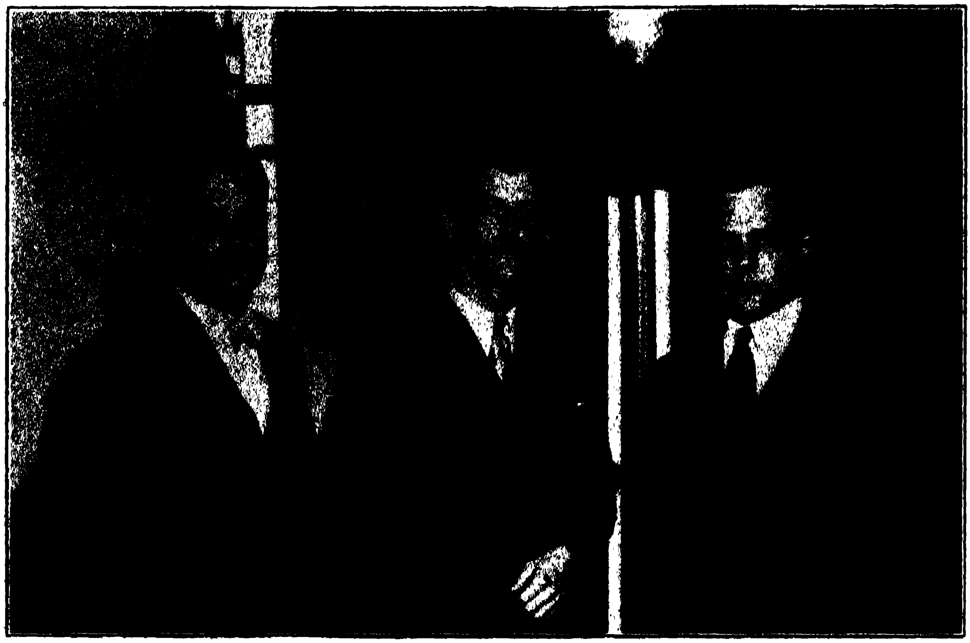
Following the close of divisional meetings at noon on Thursday, a number of Denver plants were visited, and on Friday morning the delegates scattered to various parts of the state for additional vacation trips or departed for their homes. That they were satisfied with their visit to Denver has been indicated by the many expressions of appreciation and gratification which have come to members of the local committee.

CLARENCE M. KNUDSON

AN APPARATUS FOR GENERATING HIGH VOLTAGES

CONSTRUCTION of apparatus to produce electric current of nearly 20,000,000 volts has been undertaken by Dr. Robert J. van De Graaff, research associate at the Massachusetts Institute of Technology. He has already built apparatus which produces a direct current of 1,500,000 volts. The machine he is now designing is expected to generate between 15,000,000 and 20,000,000 volts, with the ultimate possibility that 50,000,000 volts of direct current may be produced. In discussing the possibilities of this new method of generating electrical energy, Dr. Karl T. Compton remarked that no one can be certain just what the apparatus will do, but that it opens up new fields for scientific research and that a number of projects had already been outlined for investigation.

The necessity for having a very large building in which to house the new apparatus led Colonel E. H. R. Green to offer the airship dock on his estate at Round Hill, Massachusetts, where, for several years, the institute has been carrying on an extensive research program. Dr. van De Graaff's experimental generator is a comparatively simple device consisting of two brass spheres two feet in diameter which are supported and insulated from the ground by glass rods. In each sphere a belt of silk, operated by a motor at the base of the supporting rod and running over a pulley within the metal globe, conveys the electric charge to it. Here it is stored, much as the human body stores electricity generated by the rubbing of shoes on a carpet. Instead of being produced by friction, however, the charge is "sprayed" on the silk belt by a "corona" or "brush" discharge. Although this voltage "sprayed" on the belt is comparatively low, the sphere becomes charged with higher and higher voltages as it picks up the stores of electricity brought to it



THE NEW APPARATUS FOR GENERATING HIGH POTENTIALS

WITH PROFESSOR ARTHUR H. COMPTON, DR. ROBERT J. VAN DE GRAAFF AND PRESIDENT KARL T. COMPTON, OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY. THE PHOTOGRAPH WAS TAKEN AT A DINNER MEETING OF THE AMERICAN INSTITUTE OF PHYSICS IN NEW YORK LAST SPRING.

by the belt. In the present 1,500,000-volt generator each sphere is charged with 750,000 volts. As an electric pressure of 1,500,000 volts is reached, sparks fly from the brass terminals.

The importance of this type of new generator is indicated by the fact that the highest potentials hitherto available for researches have been less than 600,000 volts. In only a few laboratories in the world is a direct current of more than 300,000 volts obtainable. In every case the apparatus producing such potentials is extremely expensive, elaborate and heavy, while Dr. van De Graaff's device costs but a few hundred dollars. The experimental model generating 1,500,000 volts was built for ninety dollars. In the apparatus at Round Hill the terminal spheres will be 15 feet in diameter, and it is hoped that this apparatus will develop at least 10,000,000 volts. Each will be mounted on towers 20 feet high and constructed to permit variation of the distance between them. The operator of the apparatus will sit within one of the spheres. His body, as well as the sphere, will be charged up to several million volts, but since he will be entirely surrounded by metal this tremendous charge will have no effect upon him.

Dr. van De Graaff's discovery is expected to extend the frontiers of research. The successful development of his generator on a large scale would make possible the projection of electrons and positive ions with velocities comparable to those of radium, but in quantities millions of millions of times greater than can be obtained from any radioactive source. This would place an effective tool in the hands of the physicist, making possible further studies of the transmutation of the elements.

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RELATION OF EROSION TO VEGETATIVE CHANGES

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EXCESSIVE erosion has so profoundly changed the soil over vast agricultural areas that it is hard to understand why, until recently, systematic studies pertaining to the process and its attendant evils have been almost completely excluded from our research programs and economic theses. Undoubtedly, the neglect of this problem of continuing soil wastage and depreciation, which more than any other process alters the physical characteristics and crop-producing capacity, or plant responsiveness, of sloping land, has had closest causal relation to the prevalent conception that erosion belongs to the natural order of terrestrial dynamics—that it represents an uncontrollable agency which, through prolonged ages, has fashioned countless valleys over the world, dug prodigious canyons and otherwise accomplished an unmeasurable amount of work, part of which (that is, of normal erosion), has been beneficial to man. Geologists have given due consideration to the sharp edge of this prodigious implement of land carving, but others generally have not. There has been too much of the point of view that erosion is a necessary evil that must be borne with.

To a considerable degree, this conception is based upon substantial foundation, in so far, and only in so far, as it pertains to normal erosion. The exceedingly slow removal of surface soil, proceeding under normal conditions of ground stabilization, such as is established and approximately maintained through the instrumentalities of vegetative cover, the relatively high absorptive capacity that goes with normally developed soil porosity (an element of soil structure) and the restraining influence of gentle slope or of angle of repose. Vegetation and soil structure, separately and collectively, exert a tremendous opposing force to transportation of soil material by running water, slowing down surface removal to a point where equilibrium between rate of planation and soil building from the parent materials beneath is almost, but not quite, established. Had these more or less counterbalancing natural processes attained equilibrium some eons ago, vastly more poorly drained land of impervious claypan and hardpan characteristics unquestionably would have developed throughout the world, as well as much more of severely leached and exceedingly infertile land, such as the laterites of the humid tropics.

ABNORMAL EROSION

This paper is not primarily concerned with the effects of normal or natural erosion, except as a basis for comparison. It pertains to changed physical, chemi-

FIG. 1. EROSION, FOLLOWING CULTIVATION

HAS CONVERTED THIS LARGE AREA (SOUTHERN VIRGINIA) OF FORMERLY SMOOTH-SURFACED LAND INTO A CONDITION OF ROUGH, BROKEN LAND, WITH MORE THAN 50 PER CENT. OF THE AREA REDUCED TO ALMOST COMPLETE STERILITY, SUPPORTING ONLY A SCATTERING GROWTH OF WEEDS AND STUNTED BLACKBERRIES, AND AN OCCASIONAL PINE OR CEDAR.

cal and biologic conditions resulting from abnormal erosion, the accelerated soil washing following man's activities, his free use of axe and plow and the overcrowding of live stock upon sloping ranges. Destruction of vegetation and disruption of the natural ground structure (the structural efficiency of the soil, as pertaining to its capacity for disposing of rainfall by absorption and percolation) have caused the speeding up of erosion far beyond common belief, indeed, almost beyond the limits of comprehension.

The various phases of land wastage resulting from these disturbances of virgin soil conditions do not, then, represent a normal outgrowth of nature's operations, but, rather, the artificial development of tremendously different physical characteristics and ecologic conditions, as compared with the original soil. In their causal relationships to vegetative changes, these man-induced conditions of the soil, these results of excessive erosion, have specifically received very little attention by botanists, and much too little by ecologists, geographers, crop specialists and farmers. The fact that the earth's mightiest chasm, the Grand Canyon of the Colorado, was in the making before man arrived with his implements of destruction is no contradiction of what is averred here, for the simple reason that nothing is known of the conditions existing at that remote period. Climatic records are lacking; there is no knowledge as to the effects of possible overpopulation of herbivorous animals upon those primordial watersheds.

Removal of Humus-charged Topsoil

The most productive part of the humus-charged, sponge-like, absorptive topsoil, with its host of beneficial microorganisms and relatively high content of readily available plant nutrients, is attacked first by this accelerated erosion. In place of the original surface layer, characterized by optimum conditions (for any definite type of soil) of mellow-

ness, granulation and openness or porosity, such as favor conservation of moisture and ready penetration by fibrous plant roots seeking moisture and food, erosion-exposed subsoil is substituted through the simple process of washing off the comparatively shallow topsoil. This less productive material is of much lower organic-matter content,[1] usually is relatively higher in clay and so generally stiffer (more dense and sticky), is less absorptive of rainfall and is much more subject to running together, baking (compacting), cracking and dangerous depletion of available moisture in time of drought. Aside from the vast impairment of crop and grazing lands in the United States (and many other countries) and essential destruction of numerous areas (in the sense of economic crop production), the process has markedly altered the details of topography[2] in countless places and has entirely changed the type of vegetation that originally characterized millions of acres of farm and grazing land (Fig. 1).

This paper undertakes to emphasize these profound erosion-produced alterations in the vegetative aspects of the land. The subject can not be covered in detail at this time; its importance as a geographic, edaphic and economic problem only can be stressed here. With the pertinent quantitative data now being accumulated at the various regional soil erosion experiment stations, together with the results of soil surveys and erosion surveys,[3] the time seems appropriate for undertaking to arouse greater interest in the meaning of these newly created plant environments. At the moment, the changes and their economic significance will be defined by pointing to various representative examples. It scarcely seems necessary to observe, after what has been said, that the subject relates to destructive soil processes, as opposed to the ordinary conception of soil-building processes. Nevertheless, it is important to remember that these new soil conditions, so tremendously affecting plant adaptability and growth, are not only already wide-spread throughout the United States but are being rapidly extended, under the methods of agricultural practice in vogue, over a large proporton of the cultivated land of the nation, 75 per cent. of which, at least, is sloping and subject in varying degrees to wasteful erosion.

Relation of Soil to Vegetation

The character of the topsoil as it exists in the virgin state, from place to place, strongly influences the type of vegetation growing on it, due to the varying adaptative factors involved. These edaphic characteristics pertain not only to native and introduced plant species, but to ordinary farm crops as well. For example, it is very well known in Cuba that certain varieties of sugar-cane which grow splendidly on moist alluvial soils give exceedingly poor yields on droughty uplands; whereas, other varieties, giving but indifferent yields on precisely the same alluvial soils, get along nicely under the adverse moisture environment of the uplands. This profound effect of soil character on plant growth is strikingly revealed in many of the well-drained cane fields of the Caribbean Islands. On certain areas the plants remain green and continue to grow throughout the dry season, normally of five to six months' duration; while those of the same variety on adjacent areas

[1] H. H. Bennett, "Cultural Changes in Soils from the Standpoint of Erosion," *Journal Am. Soc. of Agronomy*, 23: No. 6, June, 1931.

[2] Numerous slopes that formerly were smooth and regular are now characteristically rough or broken, by reason of gullies that extend to depths of 10, 20, 40, 50, 75 and even 100 feet (see "Soil Survey of Stewart County, Georgia," U. S. Dept. of Agric., Field Operations (Report 15), Bur. of Soils, 1913, pp. 545–606).

[3] H. H. Bennett, "The National Program of Soil and Water Conservation," *Journal Am. Soc. of Agronomy*, 23: No. 5, May, 1931.

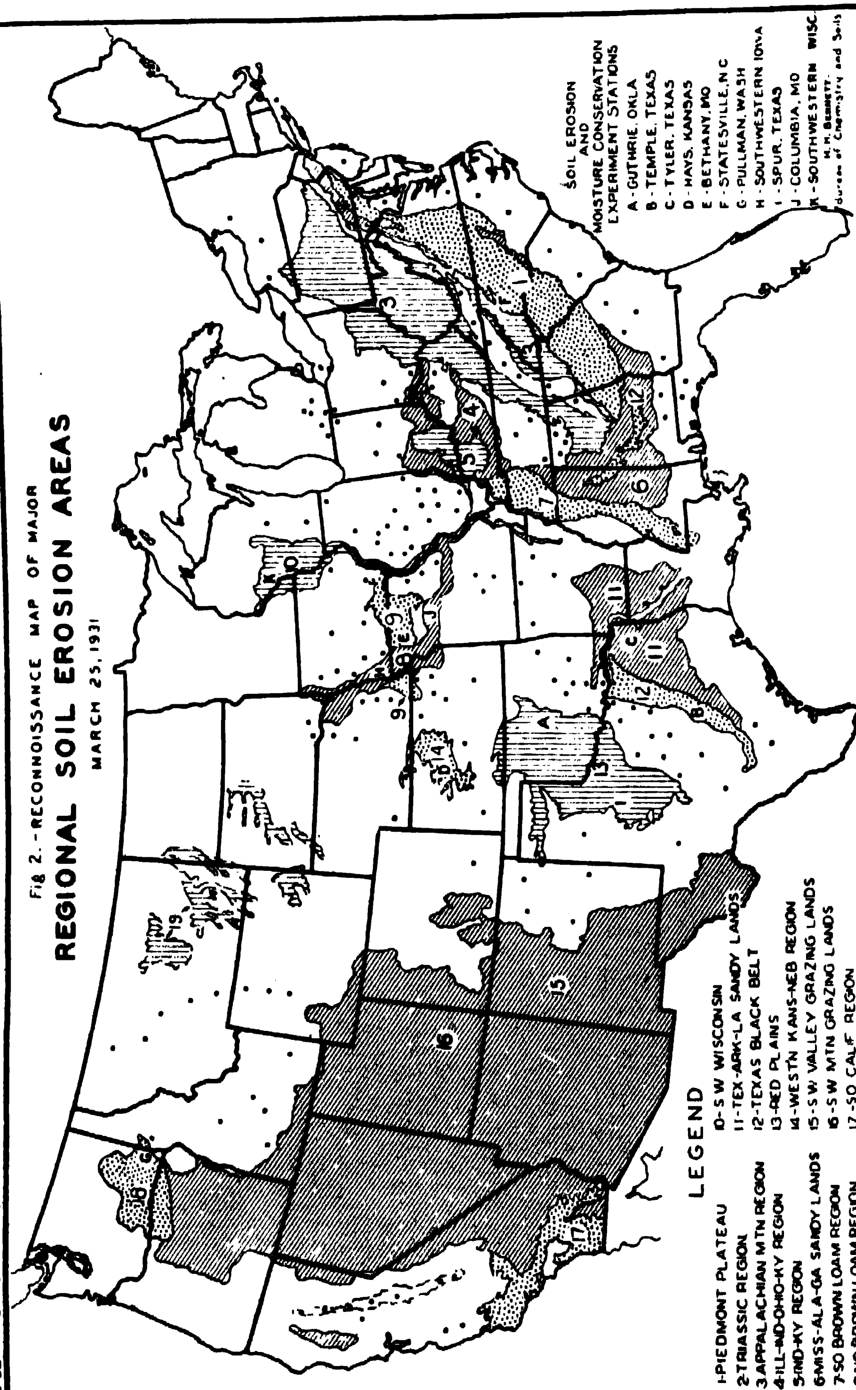
U S DEPARTMENT OF AGRICULTURE
Fig 2. - RECONNOISSANCE MAP OF MAJOR
REGIONAL SOIL EROSION AREAS
MARCH 25, 1931
LEGEND
1-PIEDMONT PLATEAU
2-TRIASSIC REGION
3-APPALACHIAN MTN REGION
4-ILL-IND-OHIO-KY REGION
5-IND-KY REGION
6-MISS-ALA-GA SANDY LANDS
7-SO BROWN LOAM REGION
8-NO BROWN LOAM REGION
9-IOWA-MO REGION
10-S W WISCONSIN
11-TEX-ARK-LA SANDY LANDS
12-TEXAS BLACK BELT
13-RED PLAINS
14-WEST'N KANS-NEB REGION
15-S W VALLEY GRAZING LANDS
16-S W MTN GRAZING LANDS
17-SO CALIF REGION
18-EAST'N WASH-ORE SILTY LANDS
19-BAD LANDS
• SCATTERED AREAS
SOIL EROSION AND MOISTURE CONSERVATION EXPERIMENT STATIONS
A-GUTHRIE, OKLA
B-TEMPLE, TEXAS
C-TYLER, TEXAS
D-HAYS, KANSAS
E-BETHANY, MO
F-STATESVILLE, N C
G-PULLMAN, WASH
H-SOUTHWESTERN IOWA
I-SPUR, TEXAS
J-COLUMBIA, MO
K-SOUTHWESTERN WISC

FIG. 2

of markedly different soil parch, stop growing or die. Examination of these areas invariably reveals that the green fields are on mellow soil, usually rich in lime and humus, such as retain favorable supplies of moisture throughout the dry period; whereas, the fields of dormant or dead plants are invariably restricted to soils which, though having the same slope and receiving the same rainfall and cultural treatment, lose their available moisture soon after cessation of the rains. Here, soil character is sufficiently potent in its relation to growth of sugarcane (and a number of other crops) to maintain the equivalent of a humid climate within a temporary desert area.[4]

Exactly the same behavior may be witnessed in the corn, wheat and cotton fields of America, especially where severely washed, soil-stripped land is associated with land still retaining its topsoil, or a considerable part of it. Almost invariably crops growing on erosion-exposed subsoil suffer much more in dry weather than those growing on uneroded soil. This is particularly true of the more succulent plants, as corn, vegetables and melons. Unquestionably the difference is the result of (a) deficiency of effective moisture (moisture available to plants) and (b) deficiency of readily available plant nutrients in the areas of exposed raw (unweathered) clay.

If soils differ in their virgin condition sufficiently to affect plant growth to the extent of counterbalancing an environmental factor equivalent to the difference between a humid climate and a desert climate, such as can be seen in the sugar-cane fields of Cuba every year, even on freshly cleared forest land, what, then, is to be expected when the original differences between two such soils are still further increased by the complete removal of that part of one of them, the humus-charged topsoil, which of all the soil layers from the surface deep into the subsoil most nearly matches the corresponding layer of the other type, and which, of all the layers, normally has the greatest capacity for manufacturing available plant food? In other words, soils whose responsiveness to plant growth varies widely in the virgin condition frequently show even greater variation, following removal of the surface layer from one of them. As between two inherently different soils, the normal tendency of erosion is not merely to minimize or eliminate the soil-equalizing effect of the organic matter and the population of micro-organisms contained chiefly in the uneroded topsoil by removing this layer; but it is to impoverish land, also, by bringing quickly to the surface unweathered, unconditioned (in relation to normal-soil plant growth) material entirely unlike and inferior to that which has been bodily swept away. If it can be called soil, then this freshly exposed material obviously is of a very different type, one constituting an entirely changed plant environment.

The Oklahoma Erosion Survey

In 1930 an erosion survey[5] of Oklahoma was completed which showed that of approximately 16,000,000 acres in cultivation in the state, 13,000,000 were subject to excessive washing, nearly 6,000,000 acres having reached the stage of gullying, with 374,000 acres, still included in fields, so badly gullied that good farm machinery could not cross the devastated areas. The survey revealed further that during the "last three or four years" 1,359,000 acres of

[4] H. H. Bennett, "Some New Cuban Soils," a supplement to the "Soils of Cuba," Scientific Contribution No. 22, Tropical Plant Research Foundation, Yonkers, N. Y., 1932.

[5] N. E. Winters, "The Oklahoma Soil Erosion Survey," Report of the Proceedings of the Second Southwest Soil and Water Conservation Conference, Circular No. 79, Oklahoma Agricultural and Mechanical College, pp. 9–11, 1931.

FIG. 3. AIR PHOTOGRAPH OF ABOUT 840 ACRES, SOUTHERN INDIANA

TWENTY-FIVE PER CENT. TIMBERED (DARK CLUMPY AREAS), WITH ONE HALF REPRESENTING RATHER SCRUBBY SECOND GROWTH ON LAND WHICH WAS ABANDONED BECAUSE OF EROSION; 11 PER CENT. PLOWED IN 1930, THOUGH PARTLY ERODED (LIGHT-COLORED GEOMETRIC PATTERNS); 64 PER CENT. ABANDONED BECAUSE OF EROSION (A—LIGHT COLORED AREAS OF IRREGULAR OUTLINE, DEEPLY ERODED AND SUPPORTING LITTLE OR NO VEGETATION, AND B—GRAY AREAS REPRESENTING FIELDS ABANDONED, NOW COVERED LARGELY WITH BROOM SEDGE). TOTAL ABANDONMENT WITHIN THIS AREA OF FORMERLY HIGHLY PRODUCTIVE LIMESTONE SOIL (OF THE GENERAL CHARACTER OF FREDERICK SILT LOAM), BECAUSE OF IMPOVERISHMENT BY EROSION, AMOUNTS TO APPROXIMATELY 75 PER CENT. OF THE AREA. THIS CONDITION OBTAINS OVER A VERY LARGE AREA IN THE LIMESTONE REGIONS OF INDIANA, OHIO, KENTUCKY AND TENNESSEE. PHOTO FURNISHED BY PURDUE UNIVERSITY AGRICULTURAL EXPERIMENT STATION.

formerly tilled land had been abandoned because of erosion.

The vegetative changes from the original virgin post oak forest and "bluestem prairies" of many localities were found to have been so great over the rolling part of the state that this feature was helpfully employed as a soil-condition indicator in connection with the classification of certain types of idle eroded land. In the Red Plains region (Fig. 2)[6] the original valuable prairie vegetation on the very extensive type of farm land, the Vernon fine sandy loam,[7] composed chiefly of *Andropogons* (as little bluestem and big bluestem), together with some grama grasses, has been replaced on the erosion-exposed, droughty red clay subsoil by an essentially worthless sod composed of weeds and such inferior forage plants as the needlegrasses.

This sweeping vegetative change has

[6] There is much eroding land of scattered occurrence outside the major regions indicated on this general map.

[7] For description of the Vernon soils, see E. H. Smies, "Soil Survey of Canadian County, Oklahoma," U. S. Department of Agriculture, Field Operations of the Bureau of Soils, 1917.

accompanied an almost hopeless decline in the economic value of a tremendous area of farm land within the Red Plains of both Oklahoma and Texas.

Hardwoods Replaced by Persimmon and Sassafras

In the east Texas sandy lands region (Fig. 2), where numerous fields have been abandoned because of erosion, thickets of small persimmon trees are very common, especially on the red soils of the Kirvin group.[8] Almost without exception, examination of these sites shows that they consist of stiff red clay or a very thin covering of comparatively infertile grayish sandy loam over red clay. Remnants of the regional virgin hardwoods, including principally oaks and hickory, reveal that all these soils once had a covering of about 6 to 8 or 10 inches of light-brown to yellow fine sandy loam over red clay, the true topsoil or humus-charged layer averaging about 4 or 5 inches in depth. This surface soil has been partly or completely removed, and the lighter colored subsurface layer also, over thousands of acres. Following such denudation, persimmon trees and smilax have sprung up abundantly, along with broom sedge, poverty grass and a variety of worthless weeds. Wherever seed trees occur, there usually has been, also, a rather wide dispersal of pine.

In the rolling areas of the formerly

[8] For description of the Kirvin soils, see B. H. Hendrickson, R. E. Devereux and E. H. Templin, "Soil Survey of Nacogdoches County, Texas, U. S. Department of Agriculture, Field Operations of the Bureau of Chemistry and Soils, 1925.

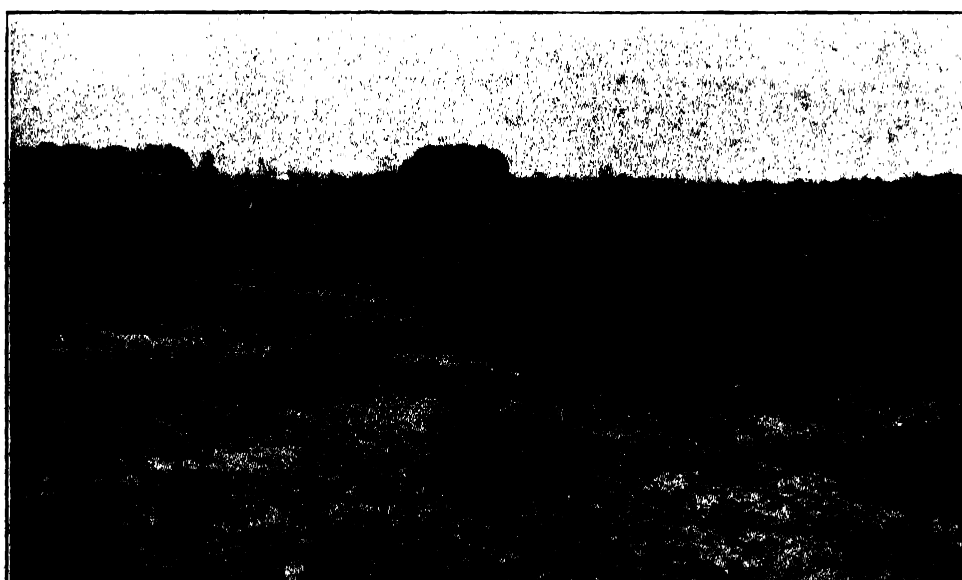

FIG. 4. ABOUT 1,500 ACRES OF FORMERLY RICH LIMESTONE SOIL HAS BEEN ABANDONED IN THIS ONE LOCALITY (SOUTHERN INDIANA) BECAUSE OF EXCESSIVE EROSION, FROM ABOUT 4 TO 8 FEET OF SOIL AND SUBSOIL HAVING BEEN REMOVED, DOWN TO BEDROCK, IN NUMEROUS PLACES. THE ORIGINAL VEGETATION WAS A HEAVY HARDWOODS GROWTH; NOW MUCH OF THE LAND IS BARE, OR ESSENTIALLY SO, AND THE REMAINDER IS COVERED CHIEFLY WITH BROOM SEDGE, POVERTY (NEEDLE) GRASS AND WEEDS, MUCH OF WHICH IS DWARFED AND OF VERY SPARSE DISTRIBUTION. PERSIMMON TREES HAVE COME IN SCATTERINGLY. THIS IS THE TYPE OF SEVERELY ERODED COUNTRY SHOWN IN AIR PHOTOGRAPH, FIG. 3.

rich limestone soils of the Highland Rim section of southern Kentucky, the thick clumps of sassafras almost universally present in abandoned fields usually mean simply one thing: That the former covering of humus-charged, mellow silt loam has been washed off down to much stiffer clay material that dries out and hardens more quickly. The vegetation coming in on the abandoned fields is entirely different from that of the hardwoods originally covering these productive uplands, and it is not known what length of time would be required for reestablishment of anything like the virgin stand of timber.

In 1930 a soil survey was completed of Washington County, Indiana, where the base map was prepared from airphotographs made during the very dry season of that year. Much land has been completely or part-time abandoned here, because of excessive soil washing—something like 25 to 30 per cent. of the entire county as indicated by the air map and soil survey. The vegetation on the critically eroded areas is so unlike that, where part of the original topsoil still remains, it was an easy matter to pick out the denuded areas on the photographic sheets. Abandoned fields which had washed down to clay were essentially bare of vegetation during the excessively dry period referred to, while those old fields which had lost all but a

FIG. 5. DEEPLY ERODED AREA OF FORMERLY CULTIVATED PIEDMONT SOIL

(CECIL SANDY LOAM) WHICH IS ESSENTIALLY STERILE. IT HAS A DECIDED ACID REACTION (pH 5.35), WHICH, HOWEVER, IS THE CONDITION OF THE FORMER OVERLYING MATERIAL, AS DETERMINED BY EXAMINATION OF THE VIRGIN PROFILE OF NEAR-BY AREAS (pH 4.87 AT SURFACE AND 5.05 AT 3½ FEET BENEATH), INDICATING IN THIS INSTANCE THAT IT IS NOT THE CONDITIONS WHICH ACCOMPANY ACIDITY BUT OTHER UNFAVORABLE CONDITIONS THAT CAUSE THE STERILITY OF THIS "RAW" CLAY. HERE SOME 3 FEET OR MORE OF SOIL AND UPPER SUBSOIL HAVE BEEN REMOVED. THE PINES IN THE MIDDLE GROUND ARE GROWING IN DEPRESSIONS WHERE MORE PRODUCTIVE EROSIONAL DÉBRIS HAS ACCUMULATED, WHILE THE HARDWOODS IN THE BACKGROUND ARE ON VIRGIN SOIL.

FIG. 6. PIEDMONT AREA

WHERE THE ORIGINAL GRANITE-DERIVED SOIL (CECIL SANDY CLAY LOAM) WAS FIRST CULTIVATED UNTIL THE SOIL WAS COMPLETELY REMOVED BY SHEET EROSION, AS WELL AS PART OF THE SUBSOIL, AND THEN ABANDONED. PINES VOLUNTARILY COVERED THE AREA, BUT FAILED TO COMPLETELY STOP THE WASHING, ESPECIALLY IN THE GULLIES. CONTINUING EROSION REMOVED THE MORE PRODUCTIVE PART OF THE SUBSOIL DOWN TO COMPARATIVELY UNPRODUCTIVE DEEP SUBSOIL, MUCH LIKE THAT IN FIG. 5; AND NOW THE PINES NOT ONLY ARE MAKING NO HEADWAY, BUT MANY OF THEM ARE DYING.

thin covering of the original silt loam supported principally broom sedge. These features are all plainly legible on the aerial map (Fig. 3).

Detailed studies of a number of the virgin profiles (vertical soil section) of the limestone soils of this southern Indiana county, which originally supported a splendid stand of oak, hickory, maple, elm, basswood, cherry, buckeye and walnut, show that the immediate topsoil of the most extensive types is considerably more alkaline than the sublayers. The deep-lying substratum material, on the other hand, is more alkaline than either the topsoil or the intermediate layers. Obviously, the plant roots, bringing up soluble basic constituents from the alkaline substratum and storing them in the leaves of forest trees, have in this indirect way transferred such alkaline material to the surface soil, to make it more productive than the layers immediately beneath. It was found that the immediate topsoil, *i.e.*, the mineral soil beneath the forest-litter, of the Frederick and Canton silt loam soils, is nearly neutral, while the various layers of the subsoil proper are of acid reaction, some of them very acid. Also, the material of the substratum was found to be acid in the upper part and decidedly non-acid (alkaline) beneath, where freshly decomposed limestone material is present.[9] It was shown, too, that the humus cover, to depths of about

[9] Data from unpublished manuscript covering the report on the survey of Washington County, Indiana, by J. T. Miller, U. S. Department of Agriculture, Bureau of Chemistry and Soils, and E. Waggoner, Purdue University.

FIG. 7. ABANDONED FORMER FIELDS, WEST-CENTRAL NEW JERSEY
FROM WHICH MORE THAN 4 FEET OF SOIL AND SUBSOIL HAVE BEEN WASHED. THIS AREA (IN WHICH PHOTOS SHOWN IN FIGS. 9 AND 11 WERE MADE) IS NOW EXCEEDINGLY POOR, ROUGHLY GULLIED LAND, ABOUT 40 PER CENT. BEING BARE AND THE REMAINDER COVERED CHIEFLY WITH POVERTY GRASS.

1, 1½ or 2 inches, ranges from approximately neutral to alkaline in every instance.

These characteristics of the successive layers through the vertical soil section afford a clear picture of what happens to the productivity of such lands under those unwise farm practices which permit the topsoil to wash off. Actually, bluegrass growing abundantly on the comparatively "sweet" (alkaline) virgin soil has been displaced, on the exposed acid, droughty subsoil, by persimmon, broom sedge and worthless weeds, with numerous areas supporting no vegetation or only scattered weeds and grass of dwarfed growth (Fig. 4).

Effect of Erosion in the Southern Appalachians

While making a reconnaissance survey of erosion conditions in the southern Appalachian region, during 1931, it was observed that the broad-leaved forests have been practically all cleared from the slopes of numerous valleys within the Blue Ridge Mountains (where the principal soils are derived from granitic rocks and micaceous schists) for a distance ranging from about a half to three quarters of a mile or more up the slopes rising from the alluvial plains bordering the streams. From about one third to more than three fourths of these formerly cultivated areas have been abandoned because of the severity of erosion. The character of the vegetation coming in after the stripping off of the surface layer (as well as the subsoil in many instances) contrasts violently with the former heavy forests of oak, chestnut, hickory, maple, sourwood, cucumber tree, tulip-poplar, rhododendron, laurel, azalea, etc. Most of the abandoned land

is covered with pine, although some areas support dense stands of tulip-poplar.

Out in the Piedmont country, east of the Blue Ridge, where erosion has devastated numerous areas, a variety of vegetative changes have taken place on the extensive Cecil soils (granite-derived soils having brittle red clay subsoils), following the gradual washing off first of the topsoil and then of the subsoil, on down into the lighter colored substratum, consisting of intermingled clay and particles of disintegrated rock. The exposed subsoil (*i.e.*, the upper subsoil) is farmed for a while with the aid of fertilizers, although all crops suffer on it during droughts, corn frequently failing completely at the same time when fairly good crops are produced on the associated less severely washed soils of the same original type. Continuing erosion lowers the surface of the ground until finally the poor, intractable deep-subsoil material is reached, at which stage the land is essentially worthless for crop production. Even the pines that grew well on the upper subsoil now fail to make much headway. They are characteristically stunted; some of them actually die as the result of continuing washing (Figs. 5 and 6).

Many of these deeply eroded areas are bare of vegetation, save for an occasional dwarfed blackberry or smilax. The broom sedge, blackberries and weeds that flourished on the upper subsoil of the fields that were thrown out of cultivation immediately following the stripping off of the surface soil usually grow

FIG. 8. SLOPE ABOVE FIGS. 7, 9 AND 11, NEVER CULTIVATED

SUPPORTING HARDWOODS OF CHESTNUT, OAK, BEECH, MAPLE, DOGWOOD, ETC. THE SOIL BENEATH THE CARPET OF FOREST-MOLD CONSISTS OF BROWNISH, MELLOW LOAM ABOUT 8 INCHES DEEP OVERLYING LIGHT-REDDISH LOAM TO CLAY LOAM CONTAINING SOME ROUNDED GRAVEL (WASHINGTON LOAM). AT DEPTHS OF ABOUT 36 TO 40 INCHES, RED CLAY, SUCH AS THAT SHOWN IN FIGS. 7, 9 AND 11, IS REACHED. ALL THE MATERIAL OF THIS ORIGINAL COVERING OF LOAM HAS BEEN REMOVED FROM MOST OF THE FORMER FIELDS ON THE SLOPES BELOW, WITH THE EXCEPTION OF THE LARGER GRAVEL; AND THE VEGETATION ON THE ABANDONED, DEEPLY ERODED AREAS IS VASTLY DIFFERENT FROM THAT OF THE VIRGIN FORESTS, AS SHOWN HERE.

FIG. 9. NO VEGETATION ON DEEPLY ERODED RED SHALE SOIL (PENN CLAY)

WEST-CENTRAL NEW JERSEY. NOT LESS THAN 4 FEET OF SOIL AND SUBSOIL HAVE BEEN ERODED FROM THIS AREA (2.9 FT. × 4.4 FT.) SINCE IT WAS BROUGHT INTO CULTIVATION. THE AREA IS STILL ERODING.

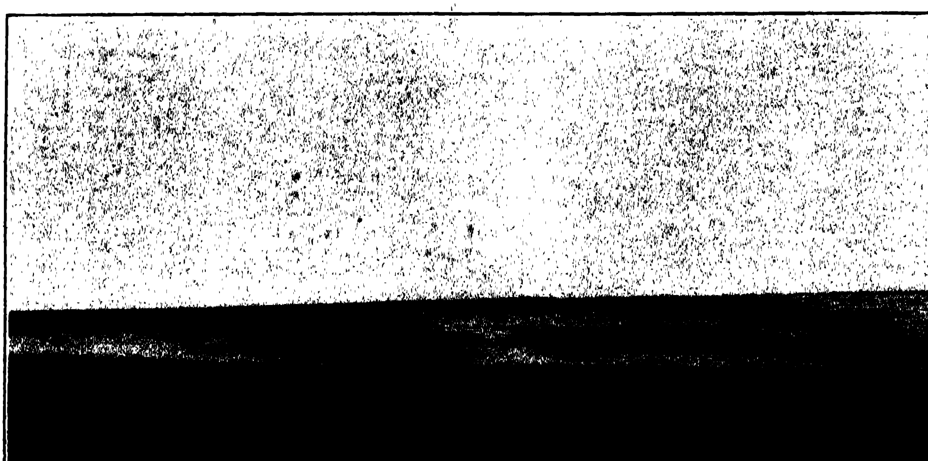

FIG. 10. PATCHY ASSOCIATION OF BLACK PRAIRIE SOIL

AND EROSION-EXPOSED WHITE SUBSTRATUM MATERIAL (CHALK), BLACK BELT OF TEXAS, NEAR TEMPLE. THE WHITE AREAS, FORMERLY COVERED WITH TWO FEET OR MORE OF BLACK TOPSOIL AND YELLOWISH SUBSOIL, ARE MUCH LESS PRODUCTIVE THAN WAS THE ORIGINAL SOIL.

stuntedly and sparsely, or not at all, on this essentially sterile material, representing the last stages of erosion before exposure of bedrock.

Lee has the following to say with respect to vegetation on the Cecil clay loam of Burke County, North Carolina,[10] an erosive soil (usually representing exposed subsoil of areas that formerly consisted of Cecil sandy loam and loam):

> Abandoned fields first grow up in broomsedge and brambles, followed the second year by sassafras, sumac bushes and yellow pine, and in a few years, except on badly eroded areas, there is a good stand of pine. Forested areas support a fair or good growth of white, red, black, post, scarlet and chestnut oaks, shortleaf or yellow pine, spruce, pitch and white pines, hickory, black gum, yellow poplar, dogwood and a few persimmon, locust sourwood, black walnut, white elm, sweet gum, red cedar and hemlock trees.

The following observations[11] relate to the far-reaching vegetative changes that have taken place over millions of acres throughout the southern Piedmont region, mainly on the Cecil soils:

> The original forest growth was quite different from the forests of the present time. On the highlands the oak, hickory, and chestnut were of large growth and stood far apart. There was no underbrush and the woods were carpeted with grass and the wild pea vine. Along the streams and in the valleys the distinctive growth was willow, beech, birch, black walnut, ash, poplar, and gum. The cane also flourished best here, although it often grew upon the higher ground. The cane growth was the standard by which the early settlers estimated the value of the land. If it grew only to the height of a man's head, the land was esteemed ordinary, while a growth of from 20 to 30 feet indicated the highest fertility.
>
> Not only the forests, but the cultivated fields as well, present a very different aspect now from what they did after the country was first opened up. It was then new and beautiful and as remarkable for the luxuriant richness of its landscape as it is now for the striking features of its rolling hills and long, narrow valleys. The original forest has disappeared almost entirely, and has been replaced by scrubby oaks, by underbrush, and by shortleaf pines of the abandoned fields. The chestnut and chestnut oaks have been dying out for the past sixty years, and the cane has likewise almost disappeared.

Second-growth pine in the Piedmont region usually means eroded land wherever found in essentially pure stands on sloping areas. Much of it grows where the original soil has completely disappeared. A rough picture of what has taken place can be formulated from conditions in Spartanburg County, South Carolina. In this one county alone 297,216 acres have been classed and mapped as clay loam and sandy clay loam.[12] Examination of the soil profile as found in remnants of the virgin stands of mixed hardwoods and shortleaf pine ("forest pine") shows the original soil to consist of some 4 to 8 inches of brownish or yellowish, mellow sandy loam and loam. This top layer is gone, or largely gone, from 297,000 acres of clay loam and sandy clay. These soils (classed as Cecil clay loam, sandy clay loam and gravelly sandy clay loam and as Louisa clay loam and sandy clay loam) are, in a sense, new soils, representing products of the excessive erosion which has taken place over the cultivated slopes.[13] Not only are they markedly different from the virgin soils tex-

[10] Soil Survey, Burke County, North Carolina.

[11] F. W. Taylor and Thomas D. Rice, "Soil Survey of the Abbeville Area, South Carolina," U. S. Department of Agriculture, Field Operations of the Bureau of Soils, 1902.

[12] W. J. Latimer, E. B. Deiter, S. O. Perkins, W. Edward Hearn and Cornelius Van Duyne, "Soil Survey of Spartanburg County, South Carolina," U. S. Department of Agriculture, Field Operations of the Bureau of Soils, 1921.

[13] Clarence Lounsbury, W. E. McLendon and J. W. Kerr have the following to say of the 70,912 acres of Cecil clay loam found in Union County, South Carolina ("Soil Survey of Union County, South Carolina," U. S. Department of Agriculture, Field Operations, Bureau of Soils, 1914): "The Cecil clay loam is formed largely by erosion, which has more or less completely removed the original sandy surface. It is an erosion-type, formed from areas

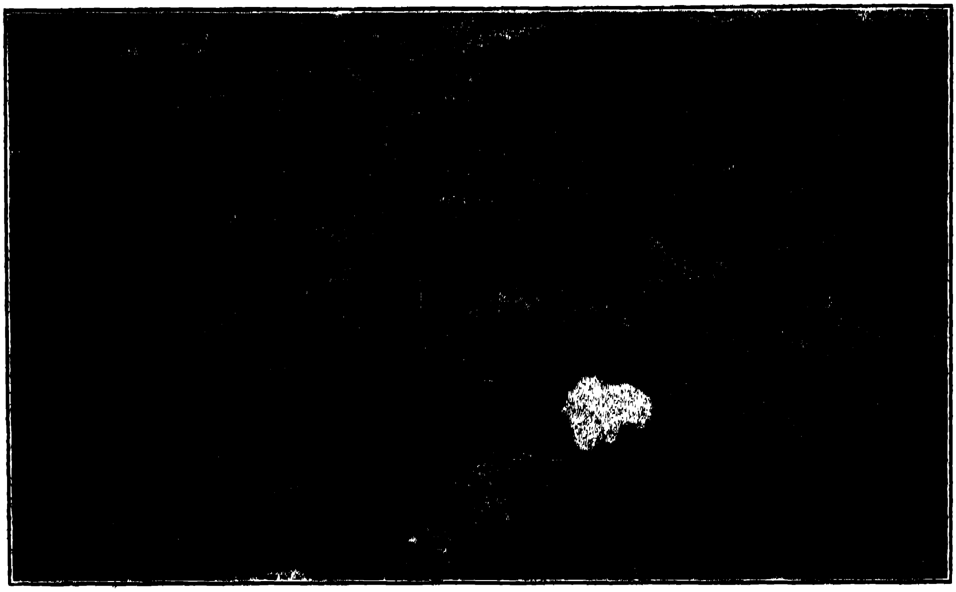

FIG. 11. SAME SOIL AS IN FIG. 9

BUT WITH LESS ACTIVE EROSION DUE TO MORE FLATTISH SURFACE AND THE PRESENCE OF A 92 PER CENT. GROUND COVER OF VEGETATION. THIS AREA (2.9 FT. × 4.4 FT.) ALSO HAS LOST IN EXCESS OF 4 FEET OF SOIL AND SUBSOIL BY EROSION. THE VEGETATION SHOWS THE FOLLOWING ESTIMATED DISTRIBUTION, WITH REFERENCE TO AREA OF GROUND COVERED: POVERTY GRASS (*Danthonia spicata*), 75 PER CENT.; POVERTY GRASS (*Aristida dichotoma*), 15 PER CENT. GROUND LICHEN, 2 PER CENT.; BARE SURFACE, 8 PER CENT.

turally (relative content of soil particles of various standardized diameters), but structurally as well. On the basis of studies pertaining to disturbed forest conditions at the erosion experiment stations (Fig. 2), on the same or similar soils, the most important structural change due to excessive erosion, from the standpoint of plant response, is a marked diminution of the effective pore space and an enormously increased tendency of the exposed clay subsoil to run together while saturated, and to bake and crack during dry periods, with consequent serious losses of available moisture. Most of the original forest of hardwoods was removed long ago from the 209,152 acres of Cecil sandy clay loam of Spartanburg County. Now about 60 per cent. of this land is under cultivation, the remainder being largely covered with old-field pine. There is an occasional second-growth white oak, hickory or dogwood and here and there are thickets of blackberry, plum, sassafras and smilax.

which formerly consisted of the more sandy types of the Cecil series.''

IN THE NORTHERN APPALACHIANS

On November 6, 1931, a forester and a soil specialist of the State of Ohio, an agricultural engineer from the U. S. Department of Agriculture and the writer walked over the erosion-denuded slopes of a large section about three miles northeast of Roseville, in the Appalachians of southeastern Ohio. From one point the view took in an abandoned area of approximately two square miles. All this had been cultivated and once was considered good soil. A fine stand of hardwoods was cut from the area long ago. Remnants of such woodlands attested the fact. Now these lands are

abandoned. The soil over the greater part has been worn away, down to a mixture of clay and shale. On this grows, principally, goldenrod, poverty grass (*Danthonia spicata*), dewberry and blackberry. Patches here and there are bare of vegetation. These lands are very acid; nutritious grasses are so scarce that a large proportion of the land is not even used for pasturage. The prevailing type of cover is of a kind that permits continuing erosion, although at a slower rate than from bare ground.

In remaining clumps of the original forest type is a good ground cover of forest litter, below this a half-inch layer of duff (mixed vegetable matter and mineral soil) and beneath the latter a 7- to 9-inch layer of yellow-brown mel-

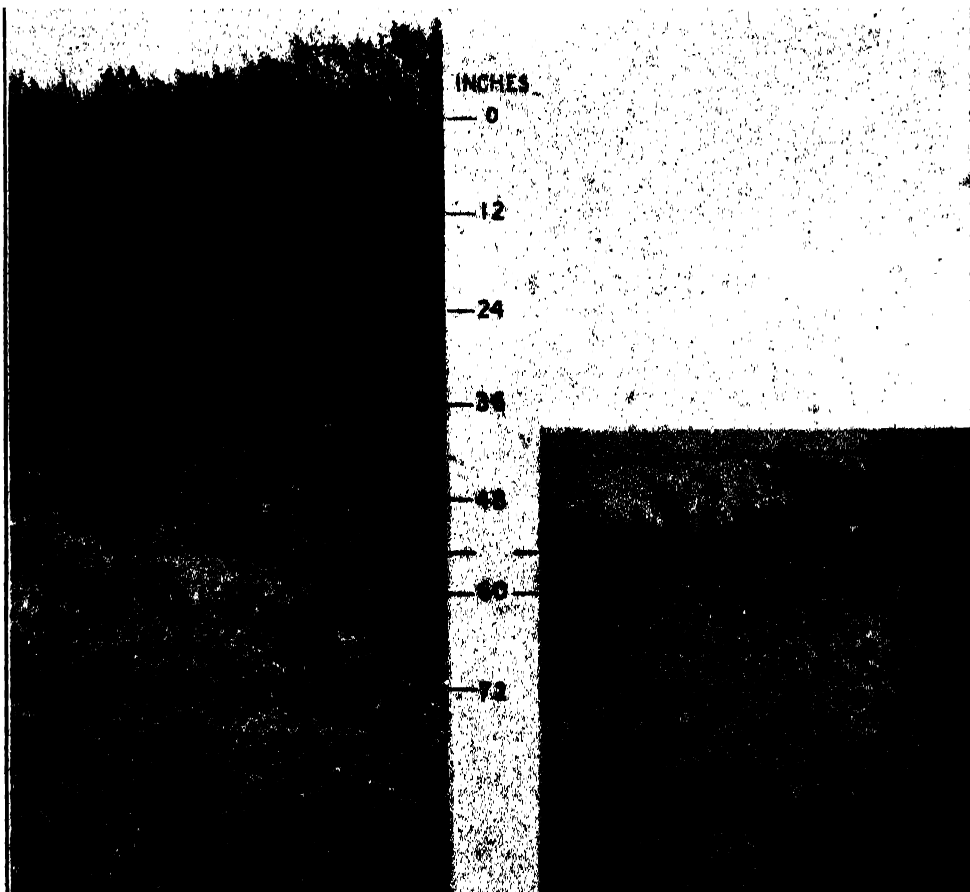

FIG. 12. VIRGIN (LEFT) AND SEVERELY ERODED (RIGHT) HOUSTON BLACK CLAY, TEXAS

BOTH AREAS ORIGINALLY WERE THE SAME, OCCUPYING A 3½ PER CENT. SLOPE. ABOUT 54 INCHES OF SOIL AND SUBSOIL HAVE BEEN REMOVED FROM THE ERODED AREA, FOLLOWING ABOUT 40 YEARS OF CULTIVATION. THE VEGETATION ON THE VIRGIN SOIL IS LARGELY COMPOSED OF GRASSES, WITH 96 PER CENT. OF THE SURFACE AREA COVERED; WHILE THAT ON THE EROSION-EXPOSED CHALK TO RIGHT (CORRESPONDING TO THE SUBSTRATUM OF THE VIRGIN AREA, AS INDICATED ON THE SCALE) SUPPORTS PRINCIPALLY WEEDS, 60 PER CENT. OF THE GROUND BEING BARE.

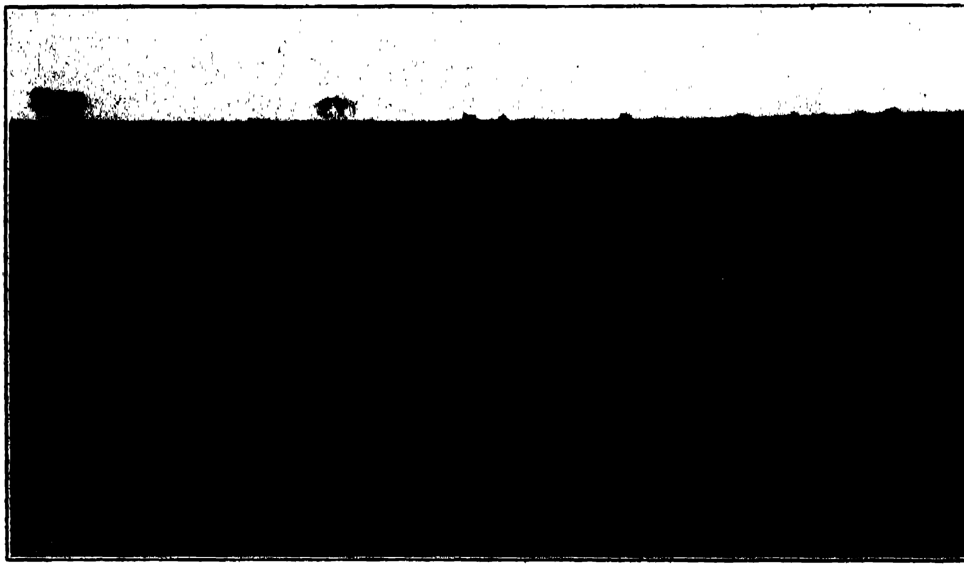

FIG. 13. VIRGIN GRASSLAND (HOUSTON BLACK CLAY, NEAR TEMPLE, TEXAS).

ONLY 5 PER CENT. OF THE GROUND SURFACE OF THIS REPRESENTATIVE SMALL SURVEYED PLOT IS BARE OF VEGETATION; GRASSES COVER 84.5 PER CENT. OF THE SURFACE (LITTLE BLUESTEM TAKING UP 43 PER CENT. AND BIG BLUESTEM 32 PER CENT.), LEGUMES 2.5 PER CENT., AND WEEDS 8 PER CENT. FRESH LAND OF THIS TYPE PRODUCES AROUND $\frac{3}{4}$ TO 1 BALE OF COTTON PER ACRE.

low silt loam, which, in turn, is underlain by from 5 to 11 inches of buff-colored silty clay and finally by a mixture of pale-yellow, acid clay and partly decayed shale fragments. This lowest section corresponds to the material now exposed over the greater part of the two square miles of eroded slopes, as well as over many thousands of acres elsewhere throughout the county.

The question was asked: "What can be done with land of this kind?" The soils-crop specialist asserted that, without reseeding, a fair stand of bluegrass could be established with the addition of lime and superphosphate, at a cost of about $10 an acre, the grass coming in voluntarily, following such treatment. It was unanimously agreed that the average farmer could not afford this expenditure on such denuded land. The forester was of the opinion that, while it would be exceedingly difficult and entirely impractical to reestablish hardwoods forest on such infertile, acid soil, conifers could be established. Again, it was agreed that farmers probably would not, upon their own resources, do much in this direction. It was further agreed by all that it was too late to accomplish very much with soil-saving measures, since so little soil was left to conserve. In other words, the soil poverty brought about by cultivating these steep slopes without provision for erosion control, resulting in stripping off from 8 to 20 inches of soil and subsoil, was so extreme that this group of specialists was unable to decide what remedy, if any, might be resorted to in order to restore these submarginal lands to any considerable degree of productivity beyond that which nature might accomplish through a long process of partial control by whatever vegetation should come in spontaneously. The mag-

nitude of the problem unfolds itself when it is considered that in the one county where this worn-out land was found there are about 200,000 acres, once cultivated, now idle, over which this condition of erosion and degraded vegetation, or an approximation of it, obtains.

Much the same thing is taking place in numerous other parts of the northern Appalachian region. Several of the accompanying pictures (Figs. 7, 8, 9 and 11) show characteristic views of west-central New Jersey, in the Piedmont section, where erosion has seriously affected a large area.

Summing up the relation of erosion to vegetative changes over immense areas formerly occupied by hardwoods and mixed hardwoods-pine forests in eastern United States, these few observations and measurements give some conception of the wide-spread changes, such as have been, in almost countless localities, about as complete as could be imagined. The vast areas of erosion-exposed subsurface, subsoil and substratum materials represent newly formed soils—new plant habitats or environments, having scarcely a semblance to former conditions, and in comparison with which they are tremendously inferior.

Changes in Texas Black Belt

Much the same thing has happened in the more rolling parts of the prairies and plains west of the Eastern forests. When it is considered that one rain, on May 10, 1930, removed 23 tons per acre of black soil (actual measurement) from a 4 per cent. slope (*i.e.*, having a fall of four feet in a hundred) of the central Texas Black Belt (Fig. 2), near Temple; and, further, that every rain causing

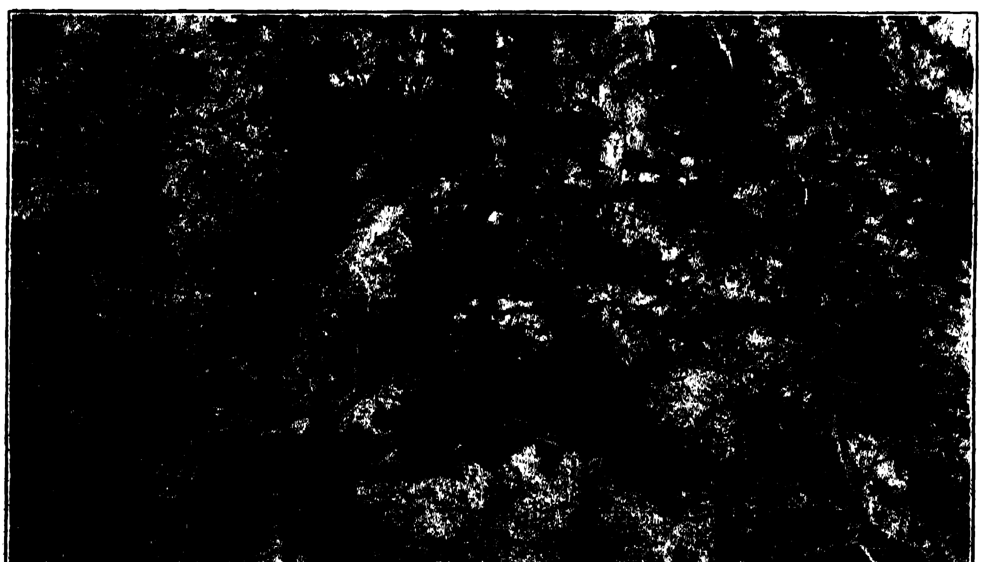

FIG. 14. DEEPLY ERODED CLAY (ORIGINALLY SAME AS THAT IN FIG. 13)

Cultivated until black topsoil had washed off, then abandoned (4 years previously). Of this surveyed area (same size as for that of Fig. 13), 75 per cent. of the ground surface was bare of vegetation. There were no grasses, but weeds occupied 25 per cent. of the surface. Land like this produces only about 1/10 of a bale of cotton per acre as an average.

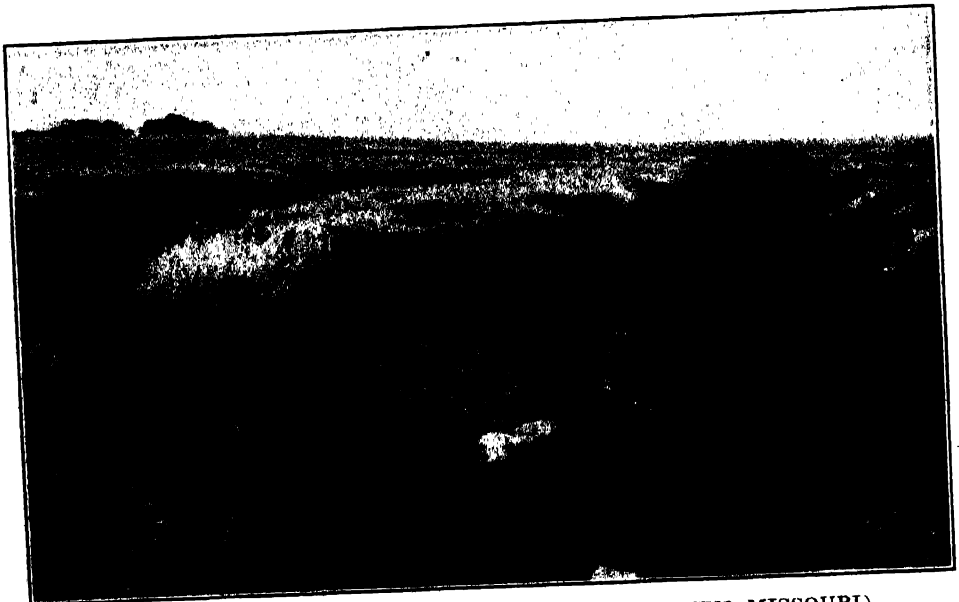

FIG. 15. VIRGIN SHELBY LOAM (NORTHWESTERN MISSOURI) WITH DENSE TURF OF BLUEGRASS (RECENT GULLYING DUE TO EXCESSIVE RUNOFF FROM CULTIVATED LAND ALONG RIDGE CREST).

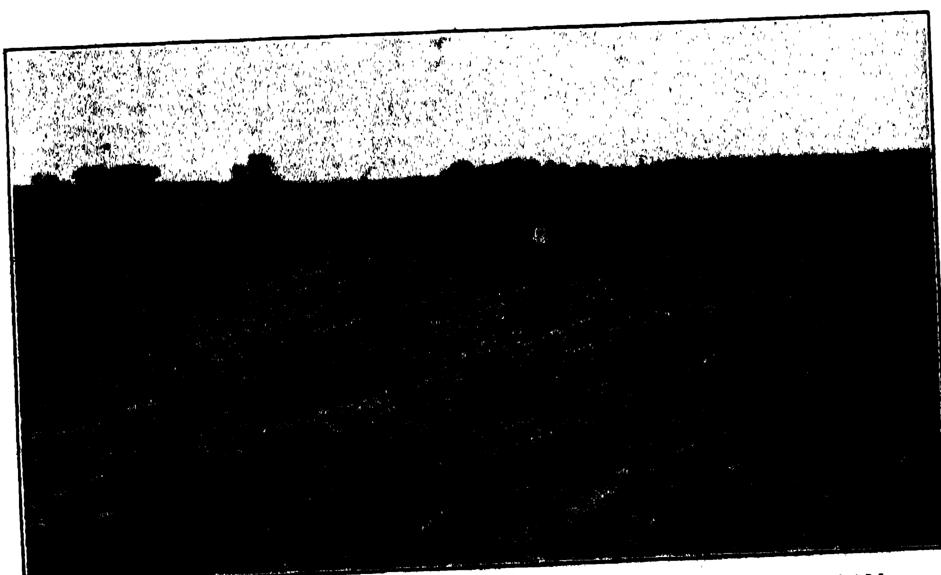

FIG. 16. CORN FAILURE ON SEVERELY ERODED SHELBY LOAM (PHOTOGRAPH MADE IN AUGUST); SAME FARM AS SHOWN IN FIG. 15.

runoffs from those areas devoted to clean-tilled crops carries away a load of topsoil, it is not at all difficult to interpret the changes now rapidly taking place in this great area of originally highly productive prairie soil—the transmutation from a genuine "black belt" to a patchy composite of rich black soil, less productive yellow clay subsoil and comparatively unproductive whitish chalk (or marl) of the erosion-exposed deep substratum (Fig. 10). The virgin soil was densely matted with nutritious prairie grasses, which in spring and early summer were beautifully sprinkled with numerous species of flowers. On the other hand, the exposed whitish chalk, resulting from forty to fifty years' cultivation, now supports sparse stands of vegetation, consisting largely of impalatable weeds; while the erosion-bared subsoil proper, the intervening layer, supports chiefly weeds and stunted grasses, with a relatively high proportion of unoccupied ground surface. The virgin soil produced upwards of a bale of cotton per acre; the exposed chalk produces at the rate of about one tenth of a bale per acre in years of favorable rainfall and at the rate of about one twentieth to one fortieth of a bale in dry years.

The results of carefully made vegetation surveys on the principal soils of the region (the Houston black clay and its exposed sublayers, as chalk and Sumter clay),[14] employing small plots of equal size (surveys carried out on same date, summer of 1931),[15] in Bell County, Texas, are given in Table 1. These surveys were made to determine as accurately as possible the vegetative changes which have taken place as the direct result of soil washing in the region (Fig. 12). The conditions revealed are duplicated, or essentially duplicated, in numerous instances (Figs. 13 and 14) throughout the extensive rolling parts of the Texas Black Belt. In connection with the changes shown in this table, it should be observed that true chalk is not present at the surface of the areas studied. Where the chalk is actually exposed, the percentage of bare ground is relatively larger than where only the yellowish-brown subsoil clay (Sumter clay) is exposed, the composition of the cover is more largely of weedy growth, and recovery with respect to reestablishment of grasses, following abandonment, has been, generally, much less.

Changes in the Shelby Loam Region

The Shelby loam, a glacial drift soil,[16] of northern Missouri, southern Iowa, northeastern Kansas and southeastern Nebraska (Fig. 2), originally was densely covered with bluegrass (Fig. 15), growing on dark-colored, mellow loam, highly charged with organic matter. Under continuous cropping to corn, this rich topsoil has been swept from innumerable areas by erosion, down to yellow clay subsoil, within a period of about 50 to 60 years, on 4 per cent. slopes, and in about 10 to 20 years on 8 per cent. slopes. The exposed stiff, yellow clay produces little grass of any value and only about 20 bushels of corn per acre (no corn in dry years), as against more than 50 bushels for the best years on the less severely washed soil (see Figs. 16 and 17).

[14] For description of Houston black clay see: W. T. Carter, M. W. Beck, E. H. Templin and H. W. Hawker, "Soil Survey of Milam County, Texas," U. S. Department of Agriculture, No. 25, Series 1925, Bureau of Chemistry and Soils.

[15] Surveys of H. V. Geib, U. S. Department of Agriculture, Bureau of Chemistry and Soils, Blackland Station, Temple, Texas, and Simon E. Wolff, Texas Agricultural Experiment Station.

[16] For description of the Shelby loam see: H. H. Kruzekopf, R. C. Doneghue and M. M. McCool: "Soil Survey of DeKalb County, Missouri," U. S. Department of Agriculture Field Operations, Bureau of Soils, 1914.

TABLE 1

COMPOSITION AND GROUND-COVER, VEGETATION ON VIRGIN AND SEVERELY ERODED HOUSTON BLACK CLAY, BELL COUNTY, TEXAS
(Eroded areas, though originally Houston black clay, now represent Sumter clay)

Ground condition	No. 1: Virgin grassland, 2–3% slope			No. 2: Severely sheet eroded, with some gullies, 3–8% slope			No. 3: 11–18 in. of soil and subsoil removed, 6–7% slope		
	Ground	Common name	Botanical name	Ground	Common name	Botanical name	Ground	Common name	Botanical name
	Per cent.			Per cent.			Per cent.		
Bare	6		......	35		......	60	......	....
Grass Cover	93			6	Buffalo grass	Bulbilis dactyloides	1	Silver beardgrass	Andropogon saccharoides
	65	Indian grass	Sorghastrum nutans						
	14	Little bluestem	Andropogon scoparius						
	9	Drummond dropseed	Sporobolus drummondii						
	4	Silver beard-grass	Andropogon saccharoides						
	1	Three-awn grass	Aristida sp.						
		Needlegrass	Stipa leucotricha						
		Big bluestem	Andropogon furcatus						
		Buffalo grass	Bulbilis dactyloides						
Weed Cover	1			59			39		
		Sensitive-briar	Morongia angustata	34	Snakeweed (Texas broom-weed)	Gutierrezia texana	18	Wreath aster	Aster multiflorus
		Kuhnia	Kuhnia glutinosa		Snakeweed (broomweed)	Gutierrezia dracunculoides	13	One-seed croton	Croton monanthyogynus
		Ruellia	Ruellia tuberosa	20	......	Hartmannia sp.	4	Kuhnia	Kuhnia glutinosa
		Prairie clover	Petalostemum multiflorum	3	One-seed croton	Croton monanthyogynus	2.75	Texas lupine (blue bonnet)	Lupinus subcarnosus (L. texensis)
		Gum elastic	Bumelia lanuginosa	2	Beebalm	Monarda sp.	1	Annual sunflower	Helianthus annuus
		Great azure sage	Salvia pitcheri		Annual sunflower	Helianthus annuus	.25	Spurge	Euphorbia bicolor
		......	Vincetoxicum biflorum		Hoary bindweed	Convolvulus incanus			
					Spurge	Euphorbia malaca			
					Spurge	Euphorbia serpens			
					Nodding spurge	Euphorbia nutans			
					Ironweed	Vernonia interior			
					Hoarhound	Marrubium vulgare			
					(Practically worthless, sometimes affording a little spring grazing.)			(Formerly cultivated, now abandoned. Not plowed or grazed for 4 years.)	

TABLE 2

COMPOSITION AND GROUND COVER, VEGETATION ON VIRGIN AND ERODED SOIL, TREGO COUNTY, KANSAS

Ground condition	No. 1: Virgin grassland			No. 5: 6–10 in. topsoil removed			No. 6: All of topsoil and part of subsoil removed		
	Ground cover	Common name	Botanical name	Ground cover	Common name	Botanical name	Ground cover	Common name	Botanical name
	Per cent.			Per cent.			Per cent.		
Bare	0	......	....	85			95		
Grass Cover	85: 80	Buffalo grass	Bulbilis dactyloides						
	10	Little bluestem	Andropogon scoparius						
	10	Blue grama	Bouteloua gracilis						
Weed Cover	15: 60	Common ragweed	Ambrosia elatior	8: 85	Redroot amaranth (pigweed)	Amaranthus retroflexus	2: 80	Redroot amaranth (pigweed)	Amaranthus retroflexus
	30	Little barley	Hordeum pusillum	10	Witchgrass	Panicum capillare	20	Witchgrass	Panicum capillare
	10	Daisy fleabane	Erigeron annuus	5	Russian-thistle	Salsola pestifer			
Old Kaffir Stubble				7			3	(Abandoned several years)	

The vegetative changes resulting from erosion on this extensive prairie soil have been extremely violent: a change from almost exclusive stands of bluegrass, in density of 100 per cent. ground cover, to scattering stands of weeds and dwarfed grasses of very low grazing value.

Erosion and Vegetation in Western Kansas

The effects of erosion with respect to soil removal in the western Kansas wheat belt are illustrated by an erosion survey (Fig. 18) of a 159-acre farm in Township 13 S, Trego County, Kansas, completed in 1931.[17]

The virgin grassland of this area, that of the upland part of Class No. 7, Fig. 18, consists of dark brown, mellow silt loam (Colby silt loam), averaging about 12 inches deep. The material beneath this top layer consists of brown silty clay, which at approximately 22 inches below the surface passes into light-brown silty clay of a limey nature. The cultivated portion of this tract, representing a typical area of highly productive western Kansas wheat soil, was broken out of plains "short grass" in 1922, just ten years prior to the making of the erosion survey. All the eroded areas are now washing at a considerably accelerated rate, as compared with the rate measured at the Hays Station on practically virgin soil of the same original type occupying about the same slope. All of the eroded areas on this Trego County farm have been markedly reduced in productivity, the most severely washed portion being excessively droughty and having very low value for the regional crops. The composition of the present vegetation on the typical virgin land, on moderately eroded land and on severely eroded land (the last formerly cultivated but now untilled), all of which originally was nearly the same with respect to soil and slope, is shown, respectively, under sites Nos. 1, 5 and 6 in Table 2.

With respect to ground cover, the change from virgin grassland condition, site No. 1, to deeply eroded, unpro-

[17] By R. H. Davis, "Soil Erosion and Moisture Conservation Investigations," U. S. Department of Agriculture, Bureau of Chemistry and Soils, Hays, Kansas, Erosion Station.

ductive land, of the class representing site No. 6, comes within 5 per cent. of amounting to a complete reversal of the virgin condition: a switch from a condition of 100 per cent. vegetated surface to 95 per cent. non-vegetated surface. The vegetation on both of the eroded sites, Nos. 5 and 6, contains not a single plant that was found in the native sod (all three plots are of equal area). This condition of change, even though approximating an extreme change, is to be seen in numerous localities within the Kansas plains, on former grassland areas. Actually, it is fairly representative of the average situation on the abandoned eroded areas of the region.

Significance of Humus Ground Cover

Reference has been made to the higher organic-matter content and greater alkalinity of the immediate surface soil, as compared with the subsoil, of various important forested soils. It might be added that the content of phosphorus is often higher, also, in this superficial layer.[18] Beyond the important fact that the mineral surface soil normally is the most productive part of the profile, the humus ground cover is a feature of enormous importance in connection with soil permanency, *i.e.*, soil protection from washing. The work of Phillips and Goddard[19] at the Red Plains Erosion Experiment Station, near Guthrie, Oklahoma, gives some conception of the true significance of ground covers. At this station the forest-litter was burned from a measured area of post-oak timber in the spring of 1930, after the area had been surrounded by a waterproof metal guard, except at the lower end, where all the runoff and washoff emptied into a tank. Another area immediately alongside the burned plot, having the same forest canopy, was similarly put under control, and left undisturbed, with its natural ground cover of leaves and twigs. In May of the same year, during a period of almost continuous rainfall, the runoff from the unburned plot was at the rate of 250 gallons per acre, while the runoff from the burned plot, having the same soil and slope, was at the rate of 27,600 gallons per acre. The excess of runoff from the burned area over that from the unburned area, plus the water-holding capacity of the leaf-litter covering the latter site,[20] was approximately 90 tons per acre. The runoff from the former area was essentially clear, while that from the burned-over ground was muddied with the products of erosion. Thus, the effectiveness of a thin cover of leaves as a protector of the soil is seen to be far greater than commonly has been supposed, and, as Lowdermilk has recently pointed out,[21] the chief function of such a ground cover is not merely to absorb water, but to send down clear water into the soil, rather than muddy water such as fills up and chokes the pore spaces developed through normal processes of soil building (as holes formed by decaying roots, insects and worms, and the natural pores that go with a mellow, humus-charged soil).

The losses from these plots for the two years 1930 and 1931 (averaged) have been: From the unburned plot, .08 per cent. of the total precipitation and .01 ton of soil per acre; from the burned

18 See H. H. Bennett, "Cultural Changes in Soils from the Standpoint of Erosion." *Jour. Am. Soc. of Agronomy*, Vol. 23, No. 6, 1931.

19 Unpublished data obtained at the Guthrie, Oklahoma, Soil Erosion Experiment Station by S. W. Phillips, U. S. Bureau of Chemistry and Soils, Superintendent of Station, and I. T. Goddard, Oklahoma Agricultural and Mechanical College.

20 The cover of leaf-litter and mold was found to have a water-absorption capacity of 33,331 pounds, or 16.7 tons, per acre.

21 W. C. Lowdermilk, "Influence of Forest Litter on Runoff, Percolation and Erosion." *Journal of Forestry*, XXVIII, No. 4, 1930.

FIG. 17. EROSION–EXPOSED CLAY SUBSOIL OF SHELBY LOAM

SUN-BAKED, CRACKED AND DRY—EXCEEDINGLY POOR SOIL: CLOSE-UP OF FIELD WHERE MAN STANDS IN FIG. 16.

plot, 2.43 per cent. of the precipitation and .15 ton of soil per acre.

In this connection, it might be mentioned that the slow rate of surface-soil building under natural conditions is indicated in the measurements of the Missouri Agricultural Experiment Station, where a 7-inch layer of topsoil (of the Shelby loam type) is removed by erosion from land sloping about four feet in a hundred, used continuously for corn, in approximately 49 years (at the rate of an annual acre loss of 20.5 tons of topsoil); as compared with about 3,000 years (annual acre-loss of .35 tons of topsoil) required to remove the same depth of surface material from bluegrass sod. Since a good sod of bluegrass probably closely approximates the ground condition obtaining where normal soil building goes on, under the humid climate of the Shelby soil region, it seems reasonable to assume that continuous corn farming as practiced by many operators in northern Missouri and southern Iowa, is causing soil losses in one year equal to a minimum of about 400 years of natural soil building.

The investigations now being carried on at all of the erosion experiment stations show that a cover of grass has a powerful effect in holding both water and soil on the slopes. For example, at the Red Plains Erosion Experiment Station, Oklahoma, the runoff from Vernon fine sandy loam,[22] occupying a 7-per cent. slope, averaged for 1930 and 1931 13.16 per cent. of the total rainfall from land cultivated continuously to cotton, as against only 1.65 per cent., for the corresponding period, from land continuously covered with Bermuda grass. The corresponding losses by erosion were 14.57 tons and .037 ton per acre, respectively. The virgin soil of the same slope and type produced for this period

[22] For description of the Vernon fine sandy loam, see W. B. Cobb and H. W. Hawker, Soil Survey of Payne County, Oklahoma, U. S. Department of Agriculture, Field Operations, Bureau of Soils, 1916.

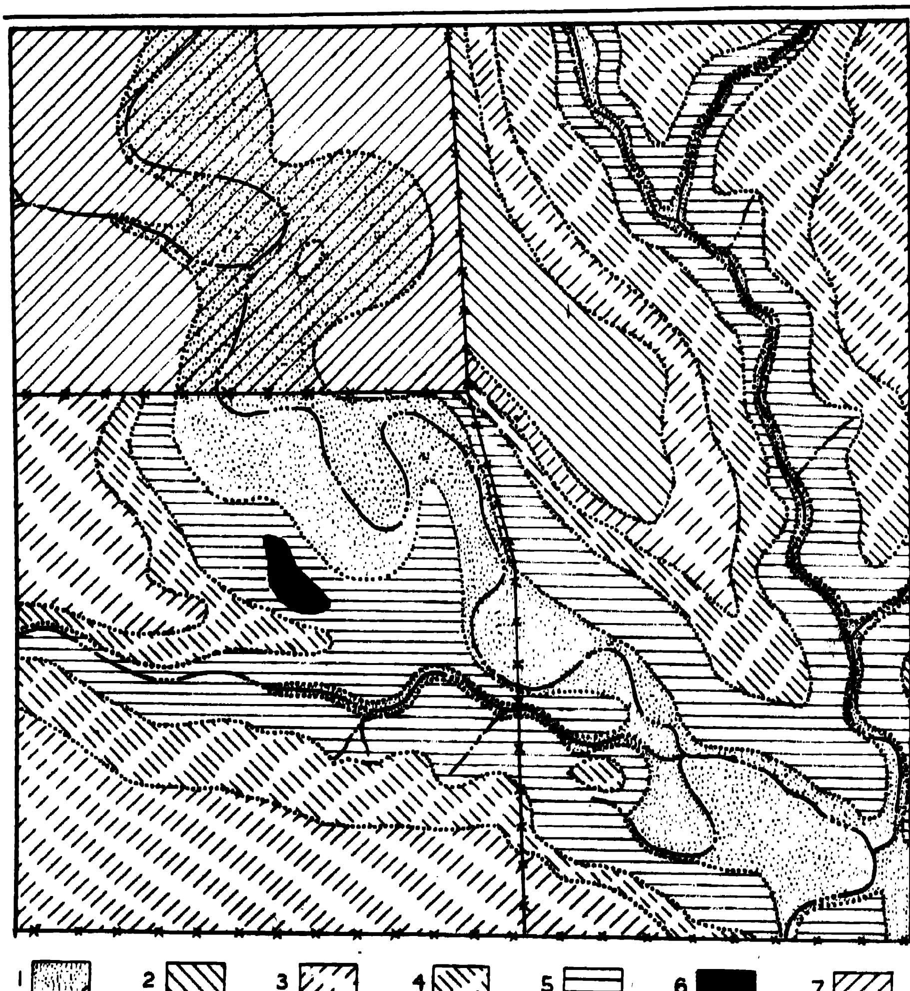

FIG. 18. EFFECT OF EROSION ON COLBY SILT LOAM, TREGO COUNTY, KANSAS

1, STREAM ALLUVIUM—NO EROSION BUT CONSIDERABLE DEPOSITION OF EROSIONAL MATERIAL (35.08 ACRES); 2, LEVEL, CULTIVATED—VERY LITTLE EROSION (7.7 ACRES); 3, GENTLY SLOPING, CULTIVATED—3 INCHES OF SOIL REMOVED BY EROSION (31.04 ACRES); 4, MODERATELY STEEP, CULTIVATED—3 TO 6 INCHES OF SOIL REMOVED (30.6 ACRES); 5, MODERATELY STEEP, CULTIVATED—6 TO 10 INCHES OF SOIL REMOVED (35.84 ACRES); 6, MODERATELY STEEP, CULTIVATED—ALL OF SOIL AND PART OF SUBSOIL REMOVED, DOWN TO 24 INCHES BELOW THE SURFACE (.5 ACRE); 7, LEVEL, AND SLOPING UPLAND AND LEVEL ALLUVIUM—VIRGIN GRASSLAND SHOWING NO EROSION (18.04 ACRES).

an average of 199.8 pounds of lint cotton per acre, while with the same rainfall the eroded subsoil, occupying the same slope (originally consisting of the same soil) averaged only 113.2 pounds per acre.

At the Bethany, Missouri, Erosion Station (Fig. 2), on Shelby loam of 8-per cent. slope, the water and soil losses, during 1931, from land devoted continuously to corn, were: 30.1 per cent. of the total precipitation and 84.08 tons of soil per acre (from a slope 73 feet long); whereas, the corresponding losses from the same soil, occupying the same slope and receiving the same rainfall, were, from continuous alfalfa: .36 per cent. of the precipitation and 2.18 tons of soil per acre. In other words, the densely growing alfalfa, constituting an excellent protective vegetative cover, held back and effected the disposal of 83 times as much of the rainfall as was retained on the corn land (chiefly by way of soil absorption and percolation), and caused, also, the saving of 38 times as much soil. The yield of oats per acre under the same conditions, for 1931, was 41 bushels per acre on virgin soil and 9 bushels on soil desurfaced down to clay subsoil.

At the West-central Kansas Erosion Station (Fig. 2), the losses of precipitational water (snow and rain) from a 5-per cent. slope of Colby silty clay loam, during 1931, were: from clean-tilled Kafir corn 11.79 per cent. of the total precipitation and 20.85 tons of soil per acre; whereas, the corresponding losses from undisturbed native sod (bluestem and other grasses, plus a few weeds) were only .05 per cent. of the precipitation and .0025 ton of soil per acre. Thus, the native plains-grass cover effected a soil-disposal of 236 times as much rain water as Kafir and caused the saving of 8,340 times as much soil. Artificially desurfaced soil (10 inches of surface soil removed) of the same original type and occupying the same slope (alongside of the Kafir and native-sod areas) lost, in 1931, 15.43 per cent. of

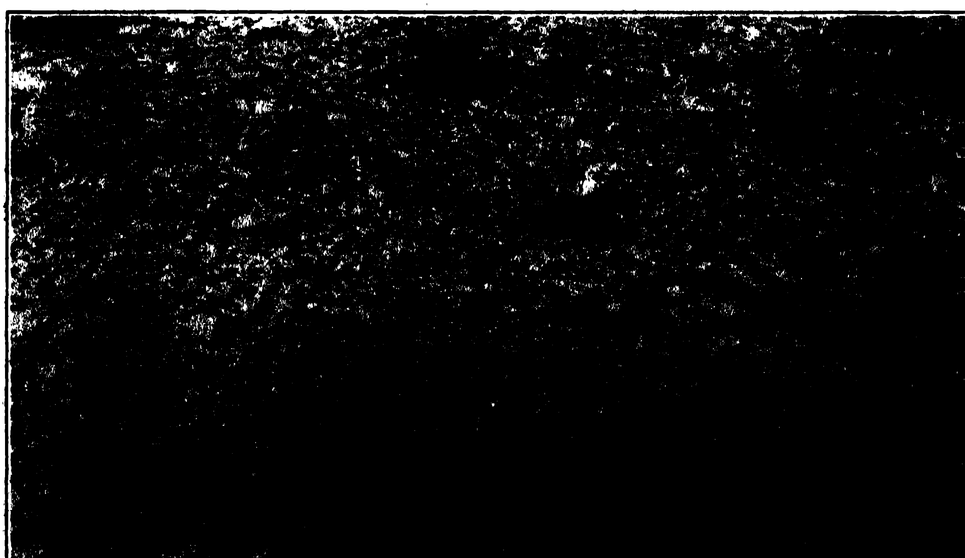

FIG. 19. ALMOST COMPLETE DESTRUCTION OF VEGETATION BY OVERGRAZING, SOUTH-CENTRAL NEW MEXICO

FIG. 20. RECOVERY OF VEGETATION
ON SAME CHARACTER OF LAND AS THAT SHOWN IN FIG. 19, CLOSE BY, AFTER A FEW YEARS OF PROTECTION FROM GRAZING.

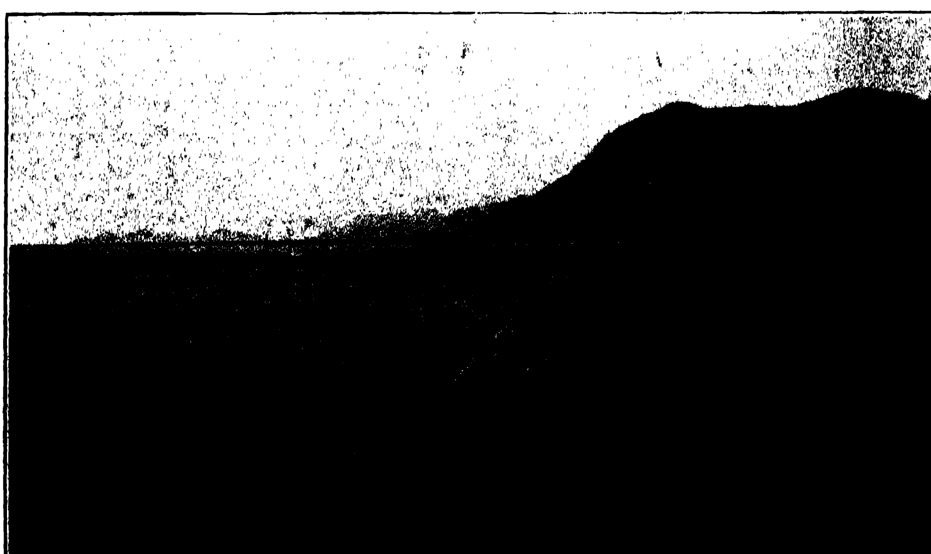

FIG. 21. SHOWING RECOVERY OF GRASS ON PROTECTED AREA
NEAR THE JORNADO RANGE RESERVE (U. S. FOREST SERVICE), NEW MEXICO.

the precipitation and 3.4 tons of soil per acre. Wheat grown under the same controlled conditions (on normal soil in the same group of plots) lost, in 1931, 2.79 per cent. of the precipitation and .27 ton of soil per acre. The acreage yield of wheat obtained from these controlled plots, in 1931, was 26.7 bushels an acre from normal soil and only 5 bushels from desurfaced soil.

Soil Moisture

Absorption and retention of moisture within the soil, in amounts available to plants, constitute a complex problem, dependent on numerous variables, such as soil texture, structure and consistence, subsoil porosity or inpermeability, character of vegetation, rate of evaporation, etc. It is not possible to discuss this phase of the problem in detail here; as a matter of fact the data available are not yet adequate for drawing final conclusions. The problem is being carefully investigated, however, on the soil-type basis, at the eleven soil erosion experiment stations located in various major soil regions (Fig. 2).

To illustrate the indicated moisture performance with respect to eroded and uneroded soil, two examples will be cited:

On April 10, 1931, the beginning of the cropping season (corn in this instance), uneroded Houston black clay, at the Temple, Texas, Erosion Station, contained 23.5 per cent. of moisture, as against 16.8 per cent. in the adjacent area of eroded soil (of the same original type). The moisture in the normal soil continued to exceed that in the eroded soil throughout the growing season, until about the time the corn began to mature, when that contained in the normal soil dropped below that contained in the eroded soil, *i.e.,* to 13.8 per cent., as against 15.9 per cent. The fact that the uneroded soil produced seven times as much corn as the eroded soil, undoubtedly explains the reversal of the moisture situation toward the end of the growing season.

On Vernon fine sandy loam, at the Red Plains Erosion Station, the soil-moisture behavior for virgin and eroded land was quite different during 1931. At about the beginning of the cotton season (May 13), the virgin soil contained nearly the same amount of moisture as the eroded soil, *i.e.,* 15.08 per cent., as against 15.38 per cent.; at harvest time (September 1), however, the uneroded soil showed a moisture content of 5.91 per cent., as against 7.12 per cent. for the eroded soil. The fact that the virgin soil produced approximately 77 per cent. more of lint cotton per acre than the eroded soil, indicates that moisture drainage by vegetative growth was very much heavier on the former. Beyond this, the moisture contents referred to do not at all mean that the total amount present was available to plants. The probability is that a considerably smaller proportion of the water enclosed within the smaller interstices of the clay of the eroded areas was available to the plants than of that contained within the larger pore spaces of the much coarser grained sandy surface soil in the virgin area. So, even with its higher moisture content, the probability is that the exposed subsoil clay, in its moisture decline from 15 per cent. at planting time to 7 per cent. at harvest time, actually lost more *effective moisture* than did the sandy surface soil, with its corresponding decline from 15 to 6 per cent.

Changes in the Southwest

In the vast domain of grazing country represented by the arid Southwest, erosion following over-grazing has caused severe denudation of an enormous area of uplands, with consequent vegetative changes, such as have seriously reduced

the grazing capacity of millions of acres of formerly fair to good range country,[23] even to the extent of 100 per cent. damage in some localities. So tremendous has been the vegetative change in consequence of this evil that it is impossible to undertake any comprehensive statement of the details here. There are areas in southwestern Texas and various parts of New Mexico, Arizona, Utah, California and other western states over which the vegetation has been completely destroyed, with little evidence of any important recovery following years of comparative freedom from invasion by live stock. Usually, however, protection from further grazing is followed by slow recovery, even from an essentially bare initial condition, to a stage where there is sufficient recuperation for the plants to give considerable protection from erosion (Figs. 19, 20 and 21). Some areas which have been swept almost bare of plant cover make a remarkable comeback under protection, due to the soil, underground seepage from higher areas and other local conditions. Such second-growth vegetation, however, is often markedly different from the original cover, particularly with respect to various nutritious grasses characterizing the original condition.

During the summer of 1929 a heavy downpour of rain six miles southeast of Panguitch, in southern Utah, swept from a 50-per cent. slope of sheep range country practically all of the grass. In many places the soil, a brown gravelly sandy loam possessing considerable mellowness, was gouged out to depths of 10 inches or more (18 inches in places). Samples collected the day following this erosive rain (August 16) showed in the uneroded soil, which had been conserved during that particular rain by protec-

[23] See H. H. Bennett and W. R. Chapline, "Soil Erosion a National Menace." Circular No. 33, U. S. Department of Agriculture, 1928.

FIG. 22. METHOD OF OVERGRAZING ALONG THE PUERCO RIVER, NEW MEXICO

MOST OF THE ALLUVIAL PLAIN HAS BEEN SWEPT OUT FROM THIS POINT, AND THIS SINCE THE COMING OF WHITE MAN TO THE REGION.

FIG. 23. SEVEN FEET OF SAND

LAID DOWN IN THE TOWN OF SAN MARCIAL, NEW MEXICO, BY THE 1929 FLOOD IN THE RIO GRANDE. LARGE AREAS WERE COVERED BY THESE DEPOSITS.

tive clumps of sage, an organic matter content of 1.4 per cent., as against .4 per cent. in the exposed lighter colored subsurface material (from which 10 inches of soil had been washed off). Such eroded areas were locally appraised as having little further value for grazing. It was asserted that grass would come back with exceeding slowness on slopes thus denuded.

Depletion of the upland vegetation has brought about a very serious problem in the alluvial plains of almost countless valleys throughout this great western grazing region. Excessive runoff from the denuded slopes has had the effect of trenching many valley plains, formerly well-vegetated, with broad channel-ways and lateral arroyos, where, 40 or 50 years ago, there was either no channel or only a diminutive run-way. In many places these channels have undercut and widened to such degree that the entire valley floor has been riddled or bodily swept out, from the foot of the uplands on one side to the corresponding position on the other side (Fig. 22). Soil, whose accumulation has taken millenniums under the slow natural process of valley filling, has been torn away completely or stripped of its productive surface material to the extent of wholly changing the vegetation remaining, or that subsequently established, for an undetermined period. Scattered creosote bushes and a few other woody shrubs are all that can be seen over some of the denuded areas which formerly were densely vegetated with nutritious grasses and herbaceous growth. This process of partial and essentially complete devastation of soil and vegetation is continuing steadily. There still remains, in some localities, enough land of approximately virgin characteristics to verify, unmistakably, what the changes have been; in other localities, where the original conditions have been essentially obliterated, there is abundant historic proof of the alterations. The student of soil conditions needs no historic proof, however, to mea-

FIG. 24. THIS FIELD OF ANTHONY SANDY LOAM

WAS CHANGED TO GILA CLAY BY THE 1929 FLOOD ALONG THE RIO GRANDE, NEW MEXICO. HERE 12 INCHES OF DENSE, STICKY CLAY WERE DEPOSITED OVER THE LOOSE SANDY SOIL.

sure the violent changes that have taken place in such areas as that of the Puerco River Valley in New Mexico, for example. Here the valley plain is fast being gouged out, and there are large areas of adjacent slopes, now nearly bare of vegetation, where the soil has been largely swept away (as shown by what is left about the protected base of an occasional brushy tree).

Changes Due to Silting

In the fall of 1929 a very destructive flood swept down the Rio Grande. The Bureau of Chemistry and Soils had completed a detailed soil survey of the alluvial plain from about the head of water in Elephant Butte Reservoir to about 11 miles above the confluence of the Rio Grande with the Rio Puerco. This flood covered so much of the surveyed area with clay and sand that most of it had to be resurveyed in 1930.[24] Areas that had been mapped as clay were changed to loose sand (Fig. 23), and sandy lands were deeply buried with clay (Fig. 24). In some places the depth of freshly deposited sand was as much as seven feet, while clay was laid down in strata exceeding two feet. Thus, droughty soils were changed to soils of good moisture retentiveness, and *vice versa*. The vegetation will necessarily undergo accordant changes.

Effect of Lowering the Watertable

Another phase of erosional effect on vegetation is represented by the lowering of the watertable following the gouging out of deep channels. A striking example is to be seen in Cañada de los Álamos, north of Los Angeles, California. Here an old arroyo, recently becoming active, cut its channel to a depth of 50 feet or more into the porous materials of alluvial and colluvial origin. The violent lowering of the watertable resulting from this channeling so changed the moisture condition that many cottonwoods of large size have recently died (Fig. 25). Similar effect on vegetation is clearly observable along the Puerco (New Mexico) and numerous other western streams.

Effect of Over-wash

A very large proportion of the alluvial plains in the Piedmont region (as well as of many other regions) has been so altered by over-wash derived from the eroding regional slopes that the soil, and

[24] E. N. Poulson and E. G. Fitzpatrick, "Soil Survey of the Socorro and Rio Puerco Areas, New Mexico." U. S. Department of Agriculture, No. 2, Series 1929, Bureau of Chemistry and Soils.

the vegetation on it, has been markedly changed. Soil that formerly consisted of loam has been buried deeply by sands of varying texture, clay deposits and silt, all so variable, both on the surface and through vertical section, that it has been impossible to classify most of the areas within the Piedmont as uniform soil types. Moreover, such land (classed as *meadow* in soil surveys) has been converted into swamp or semi-swamp by the increased overflows resulting from the clogging of stream channels with erosional débris. Formerly, these alluvial areas were heavily timbered with ash, sycamore, oak, sweet gum and pine. Much of the land was put into cultivation and considered the best of the region. Since abandonment, following the changes referred to, most of this has grown up to thickets of willow, alder, birch, blackberry, pine, rushes, cat-tail and coarse grasses.

Conclusion

Abnormal soil erosion is an impoverishing process of tremendous potency. It impoverishes the soil as well as the vegetation (including crops) that grows on it. It is hoped that this paper has presented sufficient evidence pertaining to the far-reaching effects of erosion in altering the environmental conditions of plant life to stimulate increased investigational interest in this branch of science. It should be added that, while this accentuated washing can not be completely controlled, it can be slowed down very considerably where there is a will. In determining the most effective and economic measures for accomplishing this, study of the enormous restraining capacity of vegetation, with respect to maintenance of soil and storage of water on sloping areas, opens a wide field for research and applied science.

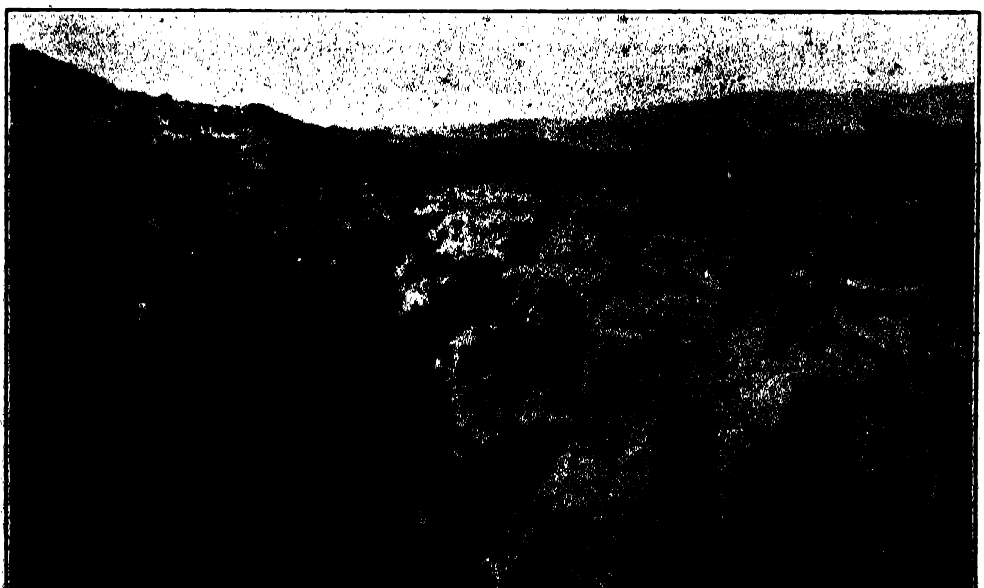

FIG. 25. COTTONWOODS DEAD (ON RIGHT)

AS RESULT OF THE LOWERING OF THE WATERTABLE BY THE RECENT ENLARGEMENT OF THIS CHANNEL (NOW MORE THAN 50 FEET DEEP IN PLACES): THE CAÑADA DE LOS ÁLAMOS, NORTH OF LOS ANGELES, CALIFORNIA. INCREASED EROSION HERE APPARENTLY THE RESULT OF MORE RAPID RUN-OFF DUE TO OVERGRAZING OF WATERSHED.

SOME PROBLEMS OF STREET AND HIGHWAY

By Dr. KNIGHT DUNLAP

PROFESSOR OF EXPERIMENTAL PSYCHOLOGY, THE JOHNS HOPKINS UNIVERSITY

THE interest of psychologists in the complex problems centering about the motor car was early aroused, and the division of anthropology and psychology of the National Research Council took official cognizance of this interest and its importance in 1924 through Dr. R. S. Woodworth, then chairman of the division. A committee on the psychology of the highway was organized in that year and delegates from the division participated in the first National Conference on Street and Highway Safety. I was the first chairman of the divisional committee, and was one of the delegates to the first and later conferences.

During the years 1927–29, I succeeded in transferring the chairmanship to Dr. A. P. Weiss, but his lamented death brought me in again. Now, the need for a younger and more active chairman has become clear, and Dr. A. R. Lauer, of Iowa State College, one of the most energetic and competent men in this field of work, will undertake the job, while I will continue to serve on the committee.

In the early years of its existence, the committee confined itself to advisory work. This was due partly to the kaleidoscopic changes in the organizations (of which there were many) studying traffic problems, and to our desire not to complicate the situation still more. In an advisory capacity we were able to supply information on various points to engineering and other organizations. In those days, the notion of increasing safety by more rigid examinations for drivers' licenses was prevalent. I believe we rendered useful service by showing that the realization of this ideal is not so simple as it appeared, and by emphasizing the impracticability of examination going beyond the minimal test of driving ability and elementary knowledge of the rules of the road.

Another matter where the dissemination of knowledge was important was in regard to signal colors. We were able to bring to the attention of the strategic groups the fact that the standards of color formerly in use were especially unfortunate, and that tests for color blindness were quite useless. The point we constantly made was that the "red" and the "green" can be made quite adequate for color-blind persons, and that the more adequate for them, the better they are for normal drivers, since it is a peculiarity of normal vision that when we direct the eyes a few degrees in any direction away from a small colored object such as a traffic light, the colors appear to us practically as they do to the typical "color-blind" person. The newer color standards are still not adequate, but we will shortly have available data from which adequate standards may be prescribed.

In 1927 conditions were more nearly clarified so that it seemed proper to commence research on leading problems. A donation of a few thousand dollars from the American Optometrical Association for work on the effects of defective vision of drivers made the time especially opportune. Dr. Weiss was interested; and Ohio State University relieved him of a part of his teaching time that he might undertake this work. With the assistance of Dr. H. F. Burtt

and Mr. A. R. Lauer, a program of basic research was commenced, and Ohio State University provided facilities and support in a gratifying way. State highway officials and individual organizations, notably the Dayton Light and Power Company, cooperated and made donations. The illness of Dr. Weiss disorganized the program, and his death and the move of Dr. Lauer to Iowa State College brought it to a close. The work on defects of vision had been forwarded, and important methods of reducing accidents in groups of commercial drivers had been inaugurated by the Dayton Company through the cooperation of Mr. Shriver and Dr. Lauer; and a number of analytic investigations contributory to the fundamental problem of the driver's relation to safety were completed. These were published in a monograph by Ohio State University in 1930. I might add that the methods worked out in Dayton have since reduced the accidents to drivers from the Dayton Light and Power Company 50 per cent., with the discharge of not many drivers. This work this year is being extended to other corporations.

Ohio State University was picked for a central research station for several reasons. Its location is sufficiently central; there seemed a chance for cooperation with important agencies; and it also seemed probable that an experimental driving field could be installed close to the university. I have always believed that such a field is essential, since laboratory tests, although an indispensable means of progress, need checking under controlled driving conditions.

With Dr. Lauer's great interest and increasing ability in the work, it seemed expedient to consider building up an experimental center at the Iowa State College at Ames. The distance from eastern centers seemed prohibitive at first, but the other advantages have finally outweighed this objection. Dr. Evans, the head of the psychology department, was much interested, and the college administration was entirely sympathetic. The results so far are highly satisfactory. A driving field has been supplied on the college tract, and substantial resources of other sorts are available, within the limited means of the college. Cooperation with the State Roads Commission and with many other agencies of state-wide or local nature seems adequate.

Work on the standardizing of signal colors is in progress. A study on proper ground colors for road signs has been completed, reported to the U. S. Bureau of Roads, and will shortly be published. Arrangements have just been made with the Iowa State Automobile Commission and the police department and traffic courts of Des Moines, through which the work on the effects of defective vision will be pushed to completion. A study of minor information signs, now a considerable danger to traffic, has been begun. A study of the legibility of license plates of different lettering and color combinations has been completed with the cooperation of the U. S. Bureau of Roads. Other investigations are on the docket.

Not all our experimental work has been confined to Ohio and Iowa. One result in Baltimore has been the working out by Inspector Lurtz of a model system of parking signs, which require no reading, but inform the drivers almost a block away as to parking limitations in the particular block. This system has been in operation for several years, and a check which we made this year shows it satisfactory and useful to drivers. Work is in progress also in Baltimore on semaphore requirements, and on headlighting and auxiliary lighting systems.

Here you have a picture of what psy-

chologists, after long analysis of the problems and careful planning, are doing in regard to traffic problems. Perhaps it is not at all what you might expect psychologists to be interested in. Psychologists are irritating in that way. They are always doing what they are not expected to do. Many people, apparently, expect psychologists to be interested in a sort of abstract "Psychology of the driver." There is no such topic, except as an abstraction; and we are not interested in abstractions. A driver is a human being, who does certain things in certain situations: situations composed of roads, cars, pedestrians, dogs, etc. You can no more study the psychology of the driver aside from these conditions than you can study insect pests apart from their breeding grounds, their available foods and their parasites.

The first thing the psychologist does, then, if he proceeds intelligently, is to analyze driving conditions; relate the requirements they make to known abilities of human beings; and then seek to find how the requirements may be bettered to suit human capacities and known human tendencies. When he finds the human ability in respect to a certain requirement is not known, then the determination of the ability is an important matter.

Next, he will take up the question of what to do about requirements which can not be adapted to the general range of the drivers, and study the problem of adaptation of the drivers themselves and the problem of elimination of unadaptable drivers. Here we run into problems of maximal complexity and difficulty. It is not a question, on the one hand, of educating drivers who are anxious to be educated. It is not, on the other hand, a question of tests of capacity which, adequately administered, would pick out the drivers who ought to be ruled off the road. Both of those problems are relatively simple. But they have really very little to do with our problem of improving traffic conditions. There are certain exceptions to this broad statement which I will indicate, but these exceptions have only minor bearing on our major problem.

The problems in which this committee has made progress illustrate very well the actual point of view of the psychologist. The street and road conditions and the particular types of cars in use make certain requirements on drivers. If these requirements are not met, there is trouble.

Now, drivers are human beings covering certain ranges of capacities and education and temperamental peculiarities. They are not standardized: there is a wide range of drivers in all these respects. If the drivers, or a considerable proportion of them, do not meet the requirements of traffic, there are two theoretical lines of progress—(1) to change the drivers; (2) to change the requirements. In the first case again, there are two possibilities. We may improve the abilities of individual drivers, through some educative process. On the other hand, we might improve the average, in another way—by eliminating the worst individuals.

On both of these points I shall have more to say, but I should like to point out here that the problem of color standards illustrates the complexity of the situation. You can't improve color vision in any individual. On the other hand, you can not by any practicable means eliminate the color-blind individuals. You can, however, change street and road conditions so that the requirements can be adequately met by the color-blind drivers. The course to take is then perfectly obvious.

The adapting of the color requirements to the driver, however, requires a competent study of the driver. No road

or street conditions have any absolute significance. They are significant only in regard to the drivers who will be placed in those conditions. We must know exactly what the color-blind man can do and can not do. Further, we must know exactly what the normal man can do in direct vision and in slightly oblique vision. This is essential to the determination of the proper conditions.

This, you may say, is a simple physiological problem. As a matter of fact, the physiological problem involved is not only unsolved, but is of no particular consequence for the practical problem. I may point out that even the determination of whether a man is or is not color blind is primarily a psychological problem, and there is no physiological test which can be applied except under tedious laboratory conditions. Determination of a man's practical color vision by simple tests is a tricky matter in which the psychologist's knowledge of the types of human reaction to test conditions is invaluable.

In studying the total traffic situation three principles have slowly clarified themselves to the psychologists.

(1) *We do not expect to increase safety except in an incidental way.* Safety is an excellent ideal, but an elusive one. Improvements in conditions do expedite traffic and make it flow more smoothly; and may make safe driving easier to attain. As soon, however, as the expediting of traffic decreases hazards, traffic immediately takes up the slack.

Let me illustrate. On a certain highway, a two-lane road, traffic became highly congested, and accidents frequent. It was widened to a four-lane road, and can now accommodate from four to eight times the traffic of the old road, with smoother flow; and it is easier driving. Was safety increased by this improvement? For a short time only. Before long, accidents began to be as numerous as ever before, and more violent. If two cars collide, several more pile on top of them. Extra efforts have been made recently by the state police, through wholesale arrests, to decrease accidents by limiting speed. Will this succeed? Look back over similar campaigns elsewhere, and answer the question yourself. Moreover, speed is only a part of the problem.

Another illustration might be found in four-wheel brakes. These expedite and smooth traffic. They have not, however, reduced the number of accidents. They have merely expedited and smoothed traffic. Other illustrations can be found, but are needless.

(2) *Under present conditions, which we see no way of changing, few persons can be prevented from obtaining driver's licenses; and any extensive attempt to limit drivers is doomed to failure.* Certain defectives—the blind, the legless, etc., can be excluded. But these are the ones who don't think that they can drive anyhow. Epileptics and a few others can be excluded theoretically, since a considerable public sentiment would be behind the exclusion. That epileptics are excluded generally, except the cases which are of a rather obvious nature, is improbable. The deaf are apparently better than average drivers. A few types, oddly enough, who are safe as the average drivers (the color blind, for example), are theoretically excluded in some states (but most color-blind persons get by the test). Any attempt to apply special capacity tests rigidly would produce a revolution, and of course would be absurd anyhow.

We believe that it is worth while to consider the practicability of efforts to determine and exclude epileptics and other specific defectives, and other cases constituting known risks. How this can be done is not at present clear.

A great number of preventable accidents and annoyances to other drivers, however, are due to reckless, erratic and ignorant drivers. These drivers are in no wise to be classed as physical or mental defectives or as lacking in capacity. Theoretically, tests could be devised for the identification of the worst of these classes. I do not even doubt that the tests could be developed practically, if a number of competent psychologists devoted their energies to it. The application of such tests, however, is another matter. We know the difficulty in keeping even the simplest tests up to standard, and we know that the administration of complex tests of sufficient precision to be determinative of mental conditions would require a vast army of skilled experts who are not available and will not be available. Under any other conditions of administration such tests would be a mere stench. Tests to be useful, or at least harmless, must be such as can be applied by the usual deputy, of modest education and political appointment. We can be certain that, for the issuing of drivers' licenses, tests can not be usefully applied which go beyond: (a) a practical driving test; (b) a few questions on the rules of the road; and (c) a test of ability to read English. The only importance of the first two of these tests, as they are administered, is that candidates do take driving lessons before coming up for examination, and do look at the book of rules. That candidates of greater competency may be flunked, and some of lesser ability passed, is true; but it doesn't matter much. Those who are flunked can try again; and the vital point is that all know they may be flunked.

Where tests which are theoretically searching, even along these lines, are attempted, they break down. This is evident from results in at least one state, which has a system of examination which appears to be excellent, but which is a farce in actual operation.

(3) *In this situation, much can still be done towards making safe driving as simple and easy as possible for all drivers.* If we make it simple for the dull or ignorant drivers, it is better for the more intelligent drivers, and *vice versa*. Further, since obstructed, erratic and tangled traffic is in itself a nuisance, and also increases the difficulties for competent and well-meaning drivers, anything we can do to smooth traffic is worth while. These seem to be the real problems of traffic and these should be emphasized.

From the psychological point of view, therefore, we must: first, determine where driving conditions can be made simpler and easier for all drivers; second, we must find out the points on which certain drivers are ignorant, and promote the instruction of these drivers; third, we must consider means by which laws can be enforced—an important matter which is of particular interest to the psychologist. Finally, the minor problem of excluding a few drivers is to be faced.

In what respects can driving be made simpler than it now is? I shall enumerate a few. (1) Traffic lights must be of the colors most quickly discernible by all drivers. Their form and placement are highly important and must be worked out on the basis of the human beings' habit of perception. When we know what the driver needs, the engineers can fill the prescription with no trouble at all. The present forms and placements of semaphores are by no means satisfactory. Accidents due to this cause may be infrequent (although it is really difficult to determine the extent to which the semaphore condition does contribute to accidents); but present conditions do confuse traffic in many cases, while in many others the requirements are such as to take drivers'

attention away from other and highly important matters. Conditions can be improved.

(2) Information signs must be conspicuous, and they must be independent of reading as far as possible. Where reading is essential, something must be done to make the reading simple. The handling of route numbers at present is excellent. But in most states local signs are sources of danger. If a driver must slow down, or stop at an intersection to study a blackboard containing a list of names of villages or a flock of arrows on a post, he makes trouble for himself and others.

An adequate system involves the consideration of what the average driver can do. It involves much more than the question of whether the blackboard of one state or the flock of arrows of another is the worse. It involves the psychological problems of background and lettering, of the systematic arrangements of names and, above all, of placement. The problem of a uniform system can be solved and is now under investigation.

(3) A great deal has been accomplished by road engineers by the use of dividing lines. These don't deter the reckless drivers, but they assist the drivers who want to be careful. I do not think this problem is finally solved.

(4) Cautionary and instructive material spread on the street surface is a nuisance. The driver who is driving properly doesn't read it: if he studies the street surface in cities it distracts him from the more important jobs. The least snow or even a sheet of water abolishes the literature, anyhow.

(5) Body designs of up-to-date cars introduce needless difficulties. The average driver who won't keep over to his side of the road may be merely hoggish, but in many cases, he really is afraid to get over, because he doesn't know where his wheels are, I know this seems absurd to the engineer whose specialty is body design; but that is because he isn't an average driver. If the designers can't cut windows lower, and set the radiator hood down, and give greater depth to the windshield, and so make the driving problem simpler without weakening the body materially, then they are not as smart as I believe they really are.

(6) Road edges have a material bearing on road-hogging. With the money spent on concrete roads, the neglect of road edges is nothing less than scandalous. In many places where cars have "gotten out of control" and so have swerved off the road and overturned, I have noticed that the road edge is the key to the catastrophe. Loose gravel, a drop of two to four inches—such conditions are common. If a car going 35 miles an hour slips a wheel off the road, will it get out of control? We all know that it will unless the driver is expecting it, or is an unusually expert driver. The results are not merely many wrecks, but also an increase in the general fear on the part of the average driver of getting over to his side of the road, especially with present cars, where the driver sits down in a closed pen looking over the high edges.

While I am on these topics, I can't refrain from referring to a road condition which has no bearing on my main problem, but which is a fertile source of fatal accidents. I refer to the solid concrete copings ("death walls" they are), which are built on the sides of culverts and small bridges. In most cases, if the driver should run his car off into the creek at one of these places, he would have a chance for his life. When he smashes into the end of the wall he has no chance at all. Some of these walls have been the cause of death after death. The same amount of concrete laid down flat, extending the width of the roadway, would have a real value.

Let us turn now to the question of ignorance. In Maryland, if the driver ahead of me hauls over to the left at an intersection, I assume that he is preparing for a right turn. If he hauls over to the right side, I assume that he is going to make a left turn. In the majority of cases, I am correct. In some cases, this is mere carelessness or disregard of the rights of other drivers. In a great many cases, however, it is just stupidity. Of course, the driver can make his turn with less trouble to himself and at higher speed in this way. I suspect that the danger and the difficulty caused to other drivers usually doesn't dawn on him. As long as everybody does it, nothing can be done about the insolent or reckless driver when he does the same thing. I have some grounds for supposing that a large number of drivers are really amenable to reason on this point; but the technique of applying the reason has to be carefully planned. In some places white-lining the intersection into alleys solves the problem: but in many streets this can not be done.

The use of hand signals is another matter in which education is important. The passing of laws doesn't seem to be an adequate remedy for this condition. On the other hand, some much-advocated systems are really dangerous. The inclination of the arm is harmless so long as you don't assume that the driver means what he seems to mean. Finger systems are a nuisance. Yet adequate systems are possible. Moving the arm up and down for *stop* and *right turn* (that is all the more difficult rotary movement amounts to), and a more or less straight and definitely motionless arm for *left turn* are definite signals. Any driver can tell whether his arm is rigid or moving, but many a man, and still more women, don't know whether the arm points up, down or straight out.

One more item of this sort, and I will leave the topic. The horn nuisance constitutes a problem which is apparently minor, yet has serious bearing and is probably responsible for more serious accidents than might be supposed. Safety and comfort would probably be enhanced by banning horns entirely, since there are few situations in which the horn is a protection, and very many situations in which it is a nuisance. It does not seem possible, however, at present to achieve this reform. This is one of those interesting points at which an accepted theory, handed down from the horse age, prevents people from observing facts. Certain ameliorations, however, might be effected. The London law, which prohibits the blowing of a horn while the car is at rest, is excellent, because it is a law which is readily enforceable. This reduces the nuisance, but it does not reduce the number of fool drivers who make horn-tooting a substitute for careful driving. A meter on every horn, with a nickel for each toot, would be something of a deterrent, but I fear is impracticable. Some means of educating drivers is the practicable solution. I think it is really a matter of ignorance on the part of most horn-tooters.

The problem of educating drivers has been discussed from many angles by many organizations, commercial and scientific. There seems to be a general agreement that two agencies are practical, from the strictly educational point of view. One is the movie, the other is the radio. From the commercial point of view, however, these do not seem so practical after all. Negotiations with film producers and distributors, I know, have been undertaken by several agencies, without success. There have been some films presented in a small way, but that sort of presentation does not cover the situation. On the other hand, it is clear that nothing stuffed

down the people's throats, or rather, into their ears and eyes, will have the desired effect. On this point, the hard-boiled attitude of the film producers is correct. I believe, moreover, that the plans proposed so far have been fundamentally wrong. Long films of a didactic type are out of date. The public is bored by them. On the other hand, there is a distinct possibility of both interesting the public and impressing them, through short episodes, one to be shown each week, each episode complete in itself and snappily worked out. I believe this method should be considered well, and with the cooperation of the auto trade a producer could be made to see its points. Nothing less than national distribution with periodic presentation would be worth while, however.

The radio has been employed a great deal in total, but not in a systematic way. Many safety addresses have been made over local systems. Here again, sporadic addresses are not productive. "Listening in" is more or less accidental, especially when the public expects the worst; and if the speaker does arouse interest this interest is not capitalized. Nothing less than a major chain broadcast, at an hour of the day when men listen, with a fifteen-minute address once a week for six to twelve weeks is worth the trouble. If such an arrangement were made, the circulation of the printed speeches in booklet form afterwards would be possible and could be easily accomplished.

In our cities, there are pressing problems of traffic, peculiarly urban. The baffling parts of these problems are their psychological features. I suppose most of the intelligent city traffic directors know the formal solutions of these problems. I know at least some directors that do; but they are helpless. Public opinion is chaotic, and steps towards the solutions can be taken only slowly, as conditions get so bad that the public recognizes that what it considers drastic steps are unavoidable.

The street surface is limited. The only traffic plan that can provide for even the immediate future is the one that makes the maximal use of this limited surface. If you use the street for garage space, you can't use it for traffic. A bus carrying forty passengers occupies no more space than two private cars carrying two persons each, or less. I have counted cars at critical points in New York, Boston, Philadelphia, Washington and other cities, at various hours of the day, and have been impressed by the fact that the majority, except in a few wholesale districts, are private cars, carrying an average of less than one person; and if chauffeurs are counted out, the average in many cases falls below one passenger. Taxis are not nearly so numerous, except immediately around railroad stations, as their bright colors would make them seem; and commercial vehicles are well in the minority, even in down-town New York.

If cars are parked solidly for the whole block in which a merchant is established, his customers can't come to his store by car. And yet merchants are convinced that congestion in front of their stores helps their business in some mysterious way.

The trouble is that the typical American wants a lot of conflicting things. He wants to be able to jump in his car, drive wherever he likes, and park his car exactly on the spot when he gets there. He wants to go as fast as he pleases, and let the devil take other drivers and pedestrians. He doesn't want the use of his car restricted, and fights every attempt to straighten out the mess, until the mess gets so bad that he finds he is wofully hampered anyhow.

This situation is quite familiar to the social psychologist. Whenever there is conflict in the satisfaction of desires, there is chaos, until it is beaten into men

that in a social group there can be no adequate satisfaction without adjustment of each man's activities to those of others. This means limitation for all, but is the only method which gives the maximal satisfaction. With every new conflict, however, we forget the lessons which past adjustments should have taught us, and each man strives to satisfy his own desires at the expense of others and fights violently against the inevitable process of social adjustment. So we have a variety of suggestions for putting the other fellow out of the way. Some have raised the cry: "Limit the use of the street by commercial vehicles," forgetting that commercial traffic is the life blood of the city. Others clamor: "Restrict street cars," "Restrict busses," although street cars and busses are the greatest economizers of precious street space. "Limit taxicabs;" in fact, each man wants to limit anything, limit everything, which will leave him more free to drive and park at will.

The remedies: In the first place, we must recognize that the real problem in cities is no longer traffic, but transportation—transportation of the maximal quantity of persons and commodities in the smoothest way. We must stop worrying about moving the maximal number of cars, and consider the most efficient means of transportation. In the second place, street space is public space, and any one who desires to use it to the exclusion or inconvenience of others must expect that within a very few years he will have to pay for the privilege. We do pay, in property taxes and gas taxes; but this is for using streets and roads as traffic lanes. For the special privilege of blocking the street with my parked car, I shall eventually have to pay rental on the space I preempt. When this principle is established—I say *when,* not *if;* for it is as certain as death—there will be plenty of capital invested in garages to take cars off the street. Definite adoption in any city of a plan of parking-space rental which should begin with a minimal charge for parking privilege tags with definite increases yearly to a reasonable limit would start a building program right now which would be an aid in this period of depression.

In the third place, we may look forward to the prohibition of private passenger vehicles from important areas in the cities, where the needs of commercial and passenger transportation can not permit this street-wasting traffic. Five years ago, traffic directors thought I was crazy when I prophesied this. They don't think so now.

These and many other readjustments are in sight. They should not come as a succession of shocks, as violent and disruptive readjustments of conditions which will have become intolerable. The public should be educated to understand the necessities and the values of the solution. The changes which are involved require readjustments of capital, readjustments of personal habits and readjustments of city systems, all of which will consume time and need planning ahead in order to prevent disastrous losses and severe inconvenience. But if the situation is not understood, if the comprehensive plans are not made, the losses and the inconveniences which must surely occur are inestimable.

All transportation in a civilized community depends on laws and law enforcement. Law enforcement is a tricky thing. Laws can be arbitrarily enforced under certain conditions, but those conditions are of brief duration, especially in a civilized community. Laws which are not accepted as reasonable and necessary by the majority of the citizens and which are not enforced uniformly are mere sources of evil, like the anachronistic blue laws of Maryland.

I do not recommend a servile obedience to law. An unreasonable, an unjust, an unfairly enforced law, it is the high duty of an American citizen to break; and if he is punished for it he ought to take his medicine like a man. All progress has been made through law-breaking. In no other way has the progressive adaptation of laws to new conditions been possible. The revolutionary patriots were law-breakers. So were all the martyrs. So are we all, although I fear most of us do not base our law-breaking on as high moral principles as did George Washington and the founders of Christianity.

I may cite the speed laws as an illustration. Was the speed limit raised from 14 miles an hour to 40 because it was seen that conditions warranted the change? No, indeed. The limits have been raised because everybody broke them, and spasms of arresting people not only did no good, but the injustice of "soaking" a few while others "got away with it" increased popular resentment. Public opinion was not behind the old speed limits, and a law without public opinion behind it would better be repealed *pronto.*

Traffic laws are essential: without them transportation would be demoralized. The question is: What laws, and how enforced? There is no simple answer to this question; and no useful answer can be obtained by appeal to formal jurisprudence. Solution of the problem involves consideration of rapidly changing mechanical situations, and a considerable amount of applied psychology.

(1) The law must fit the situation. Speed must not be prohibited where speed is a minor factor. I think Mr. Eynon of Pennsylvania has correctly estimated the situation for a state having an official speed limit. I understand that this is interpreted as a limit only where it endangers others than those in the car itself. In Maryland, the speed limit is 40, but if you drive as slowly as 40 you obstruct traffic, except during the irregular period when the police are pinching freely on a certain road. On the other hand, certain congested areas are posted for 35, for 25 and lesser numbers of miles per hour. But, practically, one is in greater danger of arrest in driving at 50 on the open road than at 40 in these highly dangerous stretches.

(2) The law must have a high degree of enforcement or be abandoned. Yet the usual speed law can not be enforced. What is the solution? Obviously, to concentrate enforcement on the dangerous stretches where the limits are low, and abandon the open road. This could be done. By concentrating on these important stretches, a real observance could be attained. A minimum of laws, really enforced, becomes respectable. More laws than can be enforced make no law at all.

What holds for speed limits holds for other aspects. Critical points should be watched. In certain cities, beating the green light became prevalent. A vigorous campaign of pinching stopped it because public sentiment was favorable. A parking limit is difficult to enforce: there are not enough policemen. But parking in forbidden places is easily detected and kept down. The whole parking problem must be faced on the basis of the determination of the rules which can be actually enforced, and abolishing other rules. Otherwise, the general flouting of regulations is inevitable.

(3) The relation of law officers to the public is the most important of all aspects in law enforcement. In some cities, the traffic cops delight in bawling drivers out; these cities are precisely those in which disregard of the most essential regulations is most flagrant. No drivers feel cooperative with the law after being treated roughly, and many

take a delight in repeating the offense in safer circumstances. This is especially evident where the offense has been due to confusion or awkwardness. On the other hand, where a different attitude is taken by the officers, cooperation is much better. Why the police force in some cities has never grasped this point is a matter I can't explain.

This hasty survey is intended to emphasize the complexity of the traffic problem, and show that there is a large place for the psychologist in cooperation with engineers, automobile makers, traffic directors, and not least, the public. It will readily be seen that it is not a field into which a psychologist can hastily plunge. No simple application of general principles is worth a fig. Nothing but prolonged study of the complex situation, leading to the picking out of vital problems, is of any consequence. There is room for active work by a number of men whose psychological training has been of the sort which fits them for the particular field. The field is great, and the workers are few. Why? Well, for one thing, because we have to do this kind of work for nothing, on our own spare time, in addition to our pretty heavy regular jobs. Naturally only a few, who get enough kick out of it to compensate for giving up almost all other amusements, Sundays and evenings included, are attracted. Another difficulty is that the more important problems require money for their running expenses, and it seems difficult to get money for this sort of work. Some of the brethren, moreover, look down on us because our efforts are not in the line of pure science.

PURE AIR FOR OUR CITIES[1]

By Dr. D. B. KEYES

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SOME time ago we were all shocked by the announcement in the newspapers that a catastrophe had occurred in the Meuse Valley in Belgium. A mysterious fog with apparent toxic properties settled down in the valley one day and caused wide-spread suffering and some deaths.

The whole world was alarmed by this catastrophe. A great many different theories were formulated by scientific men throughout this country and other countries as to the cause of this mysterious toxic fog.

It so happened that we were investigating in the Chemical Engineering Division of the Engineering Experiment Station at the University of Illinois the air pollution by sulfur dioxide formed from the sulfur contained in our Midwest coals. It was our theory at that time that sulfur dioxide from the burning of coal by industries and residences in this valley was oxidized in the atmosphere to sulfur trioxide and combined with the water in the fog to form sulfuric acid. In other words, the natives of this valley had been subjected to a rain of sulfuric acid. Apparently the atmospheric conditions were such that this oxidation could take place due to the presence of water and oxygen, and furthermore, that the sulfuric acid fell to the ground due largely to the lack of movement of air.

An official commission was formed in Belgium to investigate the catastrophe. They reported in the latter part of 1931. It is interesting to know that their final verdict on the cause of this calamity corresponded closely with our theory developed approximately a year ago.

We need not be alarmed that such a calamity will ever occur in our locality. The possibility of such a thing happening is extremely small when we recognize the fact that certain particular conditions must prevail in order to bring it about. We are, however, deeply interested in the general subject of air pollution because it is a well-recognized fact that the air in our cities is not what it should be.

Our scientific men, engineers and public officials should be congratulated on the able work that has been done in order to produce pure water for our towns and cities. On the other hand, they should be censored for their lack of interest in the problem of air purification. The residents of our large towns and cities are not only subjected to sulfur dioxide but are also required to breathe air containing a relatively high percentage of solids. This dust is not only detrimental to lung tissue and is undoubtedly the carrier of bacteria, but also it cuts down the sun's radiation to a very marked extent. One of the great problems of modern civilization is the purification of air for our cities.

This sulfur dioxide problem may be attacked in two ways; first, the removal of sulfur dioxide from the flue gases; second, the removal of sulfur from the fuel. We have done preliminary work along both lines at the University of Illinois. I am pleased to say that we have already obtained interesting and worthwhile results.

It is a well-known fact that sulfur dioxide in flue gases, even though it be present to the extent of only 0.3 per cent., may be eliminated by scrubbing the gases with water. The partial pressure of sulfur dioxide in water is unfortunately so high when it is present to any appreciable extent that it becomes

[1] The author has based this article on the work of Professor H. F. Johnstone and Professor R. D. Snow, of the Chemical Engineering Division of the Engineering Experiment Station, University of Illinois.

necessary to use enormous quantities of water. Extensive work along these lines has been done in connection with power plant development in England. Preliminary figures show that the cost of this operation is prohibitive.

Our investigators believed that it would be possible to change the sulfur dioxide to sulfur trioxide by oxidation using the oxygen present in the flue gas. Sulfur trioxide differs from sulfur dioxide in that its partial pressure in a water solution is small in comparison. It should therefore be possible to absorb the sulfur dioxide and a sufficient quantity of oxygen from the flue gases in water, in the presence of a suitable catalyst to convert the two to sulfur trioxide and sulfuric acid. Preliminary investigations have shown that both iron and manganese sulfate when present in relatively small amounts in the wash water are suitable catalysts for this particular reaction.

It was soon found, however, that there was an inhibitor present which prevented the catalyst from remaining active over a period of time. Investigations show that the inhibitor present in most flue gases was a phenolic substance. The next problem was the problem of removal of this inhibitor.

Many months were spent investigating a great many different schemes for removing this inhibitor. It was finally found that the application of a direct electric current over a short period of time would completely eliminate the inhibitor present in the wash water. An oxidation reaction takes place and apparently completely destroys the phenolic bodies. It is not necessary to apply the current except very occasionally and then for only a short period of time.

Laboratory tests and small scale tests in our power plant utilizing actual flue gases show that it is possible to eliminate approximately 95 per cent. of the sulfur dioxide present in our flue gases. These tests have also shown that one gallon of wash water will be able to treat approximately twenty-five hundred cubic feet of flue gas. This is considerably better than the results obtained in England. It is believed by men in the industry that such a process can be developed to a satisfactory scale and will become economically possible in its industrial utilization.

There are, however, other problems that must be solved before this utilization will be possible. For example, we have known that one of the great difficulties involved in large scale application of this process is the production of sufficient surface of contact between the liquids and the gases. This surface of contact is necessary in order to effect sufficient solution of the oxygen from the flue gases. A definite concentration of oxygen in the liquid is required for this reaction. We not only need sufficient contact surface but we also need sufficient time of contact. The rate of oxygen dissolution is relatively slow as compared to the more soluble gas, sulfur dioxide. This means, from a chemical engineering standpoint, that it is necessary to have scrubbing equipment which will permit a rapid changing of the liquid film.

It is recognized in all liquid gas reactions, whether they be physical or chemical, that two films exist which offer the greatest resistance towards diffusion of molecules. One is the gas film immediately above the liquid surface and the other is the liquid film immediately below the gas film. These two films are recognized to be practically stagnant under normal conditions. It is easily seen, therefore, why it is difficult for molecules, especially large ones, to pass through these films. It so happens with the less soluble gases, the liquid film is more resistant than the gas film. It will therefore be necessary to take this fact into account in the design of a suitable scrubber, and move the surface of the liquid constantly in order to minimize the liquid film. It will not be permitted to use the ordinary spray type of scrub-

ber because in this case the liquid film in the droplets remains practically stationary during the entire time of contact.

It is important, on the other hand, to utilize a type of scrubber with very little back pressure because the economics of handling these gases is such that it will be impossible for us to make use of any high pressure blowers or similar devices. In fact it is imperative to keep within a pressure not greater than that exhibited at the base of an ordinary flue. This eliminates from consideration the passage of the flue gases through a body of liquid, even though such a device would be satisfactory from the standpoint of elimination of the liquid film. Just exactly how this problem will be solved is not definitely known. We believe, however, there is a possibility of utilizing what is known as a filled column in which the liquid passes down through many channels, over the surface of a solid, coming in contact with the gases passing up.

It should be noted that whatever type of equipment is finally selected for the scrubbing of these gases it will be necessary, in all probability, to remove most of the solids present in the flue gases prior to their entrance into this equipment. Otherwise the equipment will soon become inefficient in its operation. This may be considered as a fortunate difficulty because in the last analysis the problem will never be solved until we not only remove the sulfur dioxide but all solid matter from the gases going to the atmosphere.

I have stood at the window on the upper floor of a tall building in New York City and noted the cloud overhanging the city was apparently not composed of carbon particles but inorganic matter—in terms of the power plant designer, fly ash. Analyses have shown that it is largely silica which is removed with great difficulty either by scrubbing processes or by electrical precipitation, the common methods now in use. The particles are extremely small and gravity methods are practically out of the question.

The natural conclusion is the scrubbing equipment must eliminate at least a portion of the solids from the flue gases. Experiments at the University of Illinois have indicated that the type of equipment which is necessary for the removal of the sulfur dioxide will probably remove most of the remaining solid particles.

It is my personal opinion that some of the sulfur dioxide which reaches the ground, coming originally from a flue, rides down on the surface of solid particles. We have no experimental evidence to prove or disapprove this statement. If this statement is true, any device for the removal of solid particles will materially help in the removal of sulfur dioxide.

It is recognized that no matter how successful we are in the elimination of sulfur dioxide from flue gases, the question of purifying the air in our large cities will never be completely answered by this work alone.

There are many thousands of residences in Chicago using coal as their source of heat. This coal has an appreciable percentage of sulfur and therefore if it became necessary to remove the sulfur dioxide, it would mean the installation of many thousands of scrubbing columns and chemical plants in the homes of Chicago. Such a thing from a practical and economic standpoint is utterly impossible.

It will be necessary to remove the sulfur from the coal before it is burned, a very difficult problem, in order to remedy the entire situation. We have done considerable research work in the Chemical Engineering Division here at the University of Illinois on this subject.

It is well known that there are two types of sulfur present in our Mid-west coal, one pyritic sulfur and the other so-called organic sulfur. This organic sulfur has never been isolated. No one has

ever seen it. No one has the least idea what its composition is. It is called organic sulfur because of its tendency to dissolve in certain organic solvents and because it can not be mechanically separated from the carbon and hydrogen compounds.

The pyritic sulfur can be removed to a certain extent by the well-known coal washing processes. If coal is finely pulverized so that the particles are somewhat similar in size, the pyrite, having a considerably greater density, has a tendency to fall faster through a water or any other medium than the coal particle. This is the basis of coal-washing processes.

Various engineering concerns have developed these washing processes until they have become wonderfully efficient. We can expect, however, to eliminate not much more than 20 to 25 per cent. of the total sulfur in the coal by such a process. In those cases in which mechanical cleaning is economically feasible, we feel that as much as possible of the sulfur should be removed by that method. However, even after the maximum beneficiation obtainable by mechanical cleaning has been accomplished, there still remains in the coal all the organic sulfur and also the sulfur present in the form of fine pyrite particles widely disseminated throughout the coal substance and hence not amenable to mechanical treatment. For the removal of the sulfur present in these forms, other methods of sulfur elimination, presumably involving chemical changes, must be devised.

To begin with, the pyritic sulfur can be oxidized by air when the ground coal is suspended in water, the oxidation products being largely soluble sulfates. We have found at the University of Illinois that certain catalysts speed up this reaction. Of course the higher the temperature, the faster such a reaction. It is believed possible that such a process might remove as much as 50 per cent. of the total sulfur. Unfortunately the dissolving of the sulfur oxidation products from the coal particle without the addition of mineral acids is a long and tedious process. The sulfate clings tenaciously to the surface of the carbon particle. In other words, the salt is highly adsorbed on the surface. This difficulty may prevent the process being used alone.

The ordinary coking process for coal has a tendency to drive off some sulfur. However, in the presence of such reactive gases as hydrogen, a large proportion of the sulfur is eliminated in the form of hydrogen sulfide which can be easily absorbed and removed. Our investigations at Illinois have shown that it is quite possible in the laboratory to remove approximately 60 per cent. of the sulfur in the form of hydrogen sulfide, by what might be termed an instantaneous coking process, using hydrogen or hydrogen-containing gas as the reagent. Crushed coal is allowed to fall through a zone through which hydrogen is passing. This, of course, must be done at relatively high temperatures.

It is especially interesting to note that coal treated by the air oxidation process formerly mentioned and then subjected to carbonization in hydrogen contains only approximately seven per cent. of its original sulfur. In other words, the combination of these two processes means a removal of approximately 93 per cent. of the sulfur.

It can not be said that the results so far obtained in our investigations prove conclusively that the economic removal of most of the sulfur from our Illinois and Mid-west coals is an assured fact. We do feel, however, that the results so far obtained indicate that such a process is possible, though it undoubtedly will take considerable time and energy before the difficulties involved are overcome.

These investigations should contribute materially to the final solution of the general problem of air pollution.

THE ORIGIN AND DESTINY OF ENERGY

By Dr. MASON E. HUFFORD

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ONLY a few years ago the leaders in physics had arrived at the conclusion that the greatest discoveries in physical science had already been made and that there was left for future research only a repetition of the earlier experiments, with that degree of patience and accuracy in the performance which would add certainty to one more decimal figure. Then came the discovery of x-rays and radioactivity and the isolation and measurement of electrons with all the epoch-making researches to which these gave rise. Now it is generally believed that there has been no period in the history of physics so fruitful of progress as the thirty years just passed. Physicists of to-day believe that many of the older experiments may, upon being repeated, disclose new facts and new suggestions for investigation, that no physical law is a finished and closed fact. In any of the experiments of fifty or a hundred years ago there may have been phenomena overlooked or residuals uninterpreted, which in the light of our day may be fruitful suggestions of a broader and more complete understanding.

With this present-day liberal attitude let us look at the problem of the origin and destiny of energy, to recall what notions were held regarding these concepts in the century just passed and to show how the problem is being solved in the light of the new physics of our day.

We have just witnessed the appropriate and very elaborate celebration, in London, of the centennial of the discovery by Michael Faraday of the relationship between electric currents and magnetic fields. We have had pointed out that the world in every phase has been revolutionized by that discovery. With equal appropriateness we might celebrate another discovery which barely preceded the work of Faraday, the discovery of the relation between heat and work, that is, the relation between heat energy and mechanical motion; and we might equally well say that the results of this discovery have been no less revolutionizing. In fact, the first half of the nineteenth century was marked by gigantic strides in all fields of scientific thought which have borne fruit for a hundred years and continue to stimulate the most active scientific minds of our own time. It is because of the fact that some of the ablest research of recent years has its roots back in the pioneer work of the previous century that it seems appropriate to call attention to the principal facts concerning the relation of heat and work and to the consequences of that relation.

If the students of to-day had lived only a little more than a century ago, they would have been taught that heat was a kind of fluid which could be given to or taken from bodies at will. Because the density of the heat fluid, caloric, was regarded as so immeasurably small, heat was classed along with the imponderables of that day. But such a misconception was destined to be short-lived. In fact, the whole classification of imponderables was but a blanket under which to hide want of information, and under the convincing argument of laboratory experiment it soon had to yield and disappear. Count Rumford, in boring cannon for the Austrian Government in 1798, proved that heat was developed in proportion as the boring tools became dull, and Sir Humphry Davy melted ice below the freezing temperature of water by no other means than the

friction developed by rubbing pieces of ice together. For forty years the nature of heat remained in question. Then Mayer, a German physician, observed that his patients in Europe yielded darker blood, when bled as a cure for fever, as compared to his patients in Java. He reasoned that in cooler climates greater bodily heat, accompanying better oxygenation of the blood, was secured at a greater expenditure of muscular activity. Mayer was able to make some calculations from some new work by Regnault at Paris on the specific heats of gases at constant volume and constant pressure, and these results proved his assumption that mechanical energy and heat energy can be converted, the one into the other. The next step was immediately forthcoming, that they are but manifestations of the same thing.

It should be stated that the brilliant and precise work of the English physicist Joule in 1840 finally established the identity of work and heat and their quantitative relation for all time. The experiments of Joule had as a background the theoretical work of Sadi Carnot. Carnot, a French engineer, published a paper in 1824, the results of careful observation and shrewd insight into the processes of nature which in the ideal state he called cyclical changes. He imagined that a body of perfect gas at high temperature might be drawn from a source, trapped in a closed sealed cylinder and allowed to expand. During the expansion heat disappears, temperature drops and mechanical work, that of increasing the volume of gas against resistance, is done. Now if the gas is put into the condition so the process can be repeated, it must be compressed. Compression will heat the gas, but if heat is abstracted in part, while the volume diminishes to that of the original, the temperature may be brought again to that at the beginning. The cycle has consisted in supplying heat while the gas in expansion is hot and taking it away while the gas in compression is cool, with the net result of a gain in work and a sacrifice in heat. Now the whole process of a heat-working device, which is the underlying principle of all nature's transformations as well as all man-made heat-operated machines, was summed up by Carnot in the statement that the efficiency of all heat-transforming devices is measured by dividing the heat which disappeared, that is, the quantity supplied minus the quantity rejected, by the quantity supplied. Another expression for this law of absolute efficiency is the second law of thermodynamics, which, to use the language of the German physicist, Clausius, says: "It is impossible for a self-acting machine, unaided by any external agency, to convey heat from one body to another at a higher temperature." It is clear that no heat-to-work transformation can be a hundred per cent. efficient unless there is no heat rejected, which means that when the transformation is complete the expanded gas must be absolutely cold, that is, at absolute zero, 273 degrees below the freezing temperature of water.

Now every one knows that we have, on the earth, no such ideal cold regions with which to surround our engines so that the efficiency is certain to be less than perfect. In fact, the difference between the temperature of source and sink is so small relatively that the best of our devices reaches only 50 per cent. or less. Whenever heat is drawn for the production of work it comes to us with a mortgage. That mortgage, when paid, represents the unavoidable loss. Further, due to loss by conduction and through friction, our ordinary machines entail a commission charge which must be added to the mortgage. This further increases the loss and drain on our sources of heat and raises the temperature of the sink. Every working machine we know therefore tends to

further the leveling of temperature of sources and sinks until at some distant day there must be a common temperature everywhere on the earth. From these conclusions it is clear, therefore, that from the foundations of the earth perpetual motion was outlawed.

And now look beyond the earth and consider what takes place among the stars. These are our greatest known sources of heat, of which our sun is one small example. For past eons of time these great white hot bodies have been pouring radiant energy into space. Under our older conception of limitless space this heat never could return. It meant that every blazing sun was surrounded by an infinity of volume into which the heat rays traveled forever. Here and there might be a planet which intercepted some of the radiation and whose temperature might therefore be raised, or a sun which captured a little more energy than it already had, only to pass it on again later, into the depths where its dissipation was complete.

Consideration of the fate of the heat of the universe led Clausius to speak of its inevitable loss as the "Wärmetod,"—the heat death; and Lord Kelvin, through similar reasoning, announced the general principle of the "Dissipation of Available Energy." According to this view, every century, indeed every year, sees our bank account of potential energy decreased and dissipated into heat and the heat radiated away beyond recovery, sees also a common temperature of the earth and the universe approaching. The activity of the universe, then, tends steadily toward a condition of stagnation, a "Götterdämmerung," in the language of the old German myth, which means the twilight of the gods, a condition of everlasting night when men and gods shall fall into endless rest and sleep.

And if Clausius and Kelvin have seen the picture as it is, then what of yesterday, a century ago, the beginning of our eon? There must have been a time when there was less heat energy, indeed a time when there was none. Our thought goes back to that morn of creation when the universe, wound up like a clock, was set going and before the second law of thermodynamics, with its inevitable dissipation, was made a statute. No better argument for the doctrine of the *deus ex machina* could be made. One can but wonder how much the second law and its consequences have had to do with the shaping of that doctrine. Our picture of the beginning and end of the universe is certain to be characterized by the limits of our own thinking. We attempt to base our conclusions upon facts as we see them, but the facts may not all be revealed. It will be remembered that Galileo's telescope showed the true relations of the sun, the planets and their satellites and completed the overthrow of the Ptolemaic system and established that of Copernicus.

For a period of nearly seventy-five years physicists have considered the problem of the origin and destiny of the energy of the universe. The idea that the heat of the sun and stars comes by their own combustion, as if their substance was burning coal or reacting chemicals, was early abandoned. The enormous rate of emission would bring them to cold dark bodies within a few hours or under the most favorable conditions within two or three years. More thoughtful consideration was given to the hypothesis that a rain of meteors on the sun's surface would account for the heat and light radiated. In 1854 Lord Kelvin published a calculation in which he showed that the sun's surface would necessarily acquire each year an additional layer of material sixty feet deep and that the newly received bodies must strike the sun with a velocity of 276 miles per second in order to produce the outflow of energy. It is doubtless true that some small fraction of the sun's

energy is produced in this way, but it is doubtful whether it is any considerable part of the whole.

A much more plausible theory of the origin of stellar energy was that of condensation. If the sun's mass was originally in the vapor state, vast amounts of energy must have been liberated while it contracted to the present size. In the light of the newer physics, Sir Arthur Eddington at Cambridge has determined an upper limit for the age of the sun from the energy produced by its contraction since a temperature of 3,000 degrees was reached. He concludes that the sun has existed for about twenty million years. While this is a vast period of time it will be seen that it is too small to meet the demands of the biologist, geologist and astronomer.

There have always been minds to which the "Wärmetod," the idea of the dissipation of available energy and the consequent asymptotic ending of the universe, is not satisfactory. There are those who doubt whether the second law of thermodynamics is always and everywhere true. Perhaps even now somewhere in the universe there is a source of potential energy, where new available energy and heat are being created. Whatever the final facts are found to be the ultimate end of the universe has been greatly postponed if not indefinitely removed. The down slope of the energy-time curve has been found to be much less than it was thought to be half a century ago.

One of the greatest contributors to our increased breadth of view is Einstein. Whatever challenge his theory of relativity may yet have to meet, we must admit that in much it has been signally victorious. One of its foremost successes is its prediction of the identity of matter and energy. Maxwell at Cambridge in 1881 predicted in his electromagnetic theory of light that a beam of radiation incident on an absorbing surface should exert pressure on that surface equal to the energy of the beam. Lebedew at Moscow and Nichols and Hull at Dartmouth experimentally verified the existence of light pressure and proved therefore that radiation has momentum, one of the defining properties of matter. The impact of the sun's radiant heat and light upon the earth exerts a force which totals 60,000 tons.

While we had left to us the ether of space so fundamental in Maxwell's theory, the momentum of light was associated with the mass of the ether and our concepts of matter and energy were separate, but since Einstein, in his theory of relativity, finds no need for the ether we now must identify the momentum with the light energy itself, which is to say, that matter and energy are the same thing. As a confirmatory proof of this identity, the eclipse expeditions of 1919 and 1922 reported that the light of stars was curved from its straight line path when passing close to the sun, exactly in accord with the calculations based on the theory of relativity. This has been regarded as strong proof of the material nature of radiant energy.

Assuming that matter and energy are the same, Sir James Jeans has shown that a body which radiates energy at the rate of 50 horse-power loses weight at the rate of one and one fourth grams per century. By the same calculation the sun is exhausting its mass at the rate of 250 millions of tons per minute. Therefore the sun weighs 360,000 million tons less to-day than yesterday. Five or ten million years ago our sun was twice as large as now.

In this process of direct transformation of matter into energy the method represents the maximum possible efficiency. Compared to it our engines yield about one one hundred millionth of one per cent. If a drop of water were wholly transformed to energy it would yield 200 horse-power continu-

ously for a year. On this basis a pound of coal would do the work for which we now require five million tons. In this process there is no sink, there is no ash, no heat waste, all mass becomes energy. Out of an atom an electron escapes to freedom and finding a like privileged positive ion, the two are paired in an everlasting union and annihilation—a train of waves starts across space. Atoms and electrons are done away, and in their stead there appears a blazing star.

In another important respect relativity has brought us a change in our point of view—that regarding the limits of space. What we formerly thought was an unlimited universe has come to be bounded and limited. Just as by measuring the curvature of a limited portion of the earth, its radius can be determined, so in an analogous way the density of the distribution of matter determines the size of the universe and shows that space is rounded back on itself. Some idea of the immensity of the universe may be obtained by measuring distances by the velocity of light. We know that light will travel seven times around the earth in a second. It will pass around the universe in 6,000 millions of millions of millions of years. If the earth were represented by the size of an atom, then the limits of our largest telescopes would be the radius of the earth, and the universe is a thousand million earths. This is a measure of our change of understanding of our universe since the time of the first astronomers.

Within the time in which our views regarding mass and space have changed, our ideas regarding the age of the earth have also been modified. No one now believes that the Biblical record of the earth's history was meant as an accurate statement of time. The infallible record is written in the earth's structure itself, although the interpretation is somewhat difficult. A seemingly successful method of measuring the age of the earth is offered by determining the ratio of quantities of uranium and lead found in the igneous rocks. The history of the method dates from the discovery of radioactive matter by the French physicist Becquerel, in 1896. About ten years later Rutherford and Soddy at Montreal showed that radium, which represents the fifth transformation of matter after uranium, disintegrates into two gases, radon and helium. The radon disintegrates in turn through four generations and finally becomes lead. From the rate of the formation of lead and the mass ratio of uranium to lead found in the rocks, it has been calculated that 200 million years have elapsed since the rocks of the coal age were formed. The lower Precambrian rocks are 1,300 million years old. And these rocks are intrusions in the sedimentary rocks, so that the ocean has a still greater age. By this method of estimation Professor Russell at Princeton has shown that the age of the oldest rocks is at least 2,000 million years. Now if the temperature of the earth in the original gaseous state can be safely estimated, the laws of cooling are sufficiently well established to determine the time required for the gas mass to become liquid. Making reasonable assumptions for the energy content of the earth vapor, figures show that 5,000 years were required for the earth's liquefaction and 10,000 years for its solidification. It is very probable therefore that 15,000 years elapsed before the oceans were condensed and came into being.

In considering the rôle of condensation in the production of heat and light of stars, Eddington at Cambridge has made some calculations on the bright pulsating star delta-Cephei. This interesting star is 700 times brighter than our sun and 60,000 times farther from the earth. It has a mass ten times greater than the sun and a temperature

which varies from 6,000 degrees at the surface to six million degrees at the center. It fluctuates in brightness from a maximum to a minimum in five and one third days. If condensation accounts for the brightness, then the period of pulsation should change by seventeen seconds per year. Observations show, however, that since 1848 the period has been entirely uniform and the change since 1785 has been less than 1/150 of what it should be.

Eddington has pointed out also that in order that the star mass may not collapse under the enormous pressure of the upper layers there must be a large temperature gradient from center to circumference. Either the acquisition of meteoric bodies or the condensation of mass must add energy only to the outside and collapse can not be prevented by feeding the gradient at the wrong end. Eddington concludes therefore that neither hypothesis can account for the energy, although either may contribute a part.

At the present time the physicist knows of only three possible ways by which the heat of the universe can be produced, the breaking down of complex elements as in radioactivity, the building up of more complex elements from simpler ones and the complete transformation of matter into energy. The last of these has been accepted by Jeans and Eddington.

Early studies in radioactivity showed that a mass of radium evolves enough heat every hour to melt its own weight of ice, and twelve hundred years are required for half its mass to transform into its products, radon and helium. But if the enormous heat of the stars is to be explained on the basis of radioactivity then there must be assumed in the stars the presence of elements tremendously more radioactive than any we now know on the earth. It is not at all likely that absolutely every trace of such elements should have been entirely erased from the rock records of the earth's history.

The second of the methods has been suggested by two contemporary lines of research, both of which originated at Cambridge. Through a period of twenty years Sir Ernest Rutherford and his co-workers have shown that gases, nitrogen, oxygen, chlorine, etc., when bombarded by alpha particles, that is, positively charged atoms of helium, have their molecules and atoms broken up. Analysis of the products by a magnetic field reveals the presence of hydrogen from such collisions.

Parallel with these successes Aston has analyzed, also by a magnetic field, the gas atoms which have been disintegrated by the rough treatment received in a low pressure tube which transmits an electrical discharge. From the interpretations of the mass spectra in these experiments we know that the nuclei of the heavier elements are aggregates of the nucleus of hydrogen.

Aston has pointed out that if the atom of oxygen is given the atomic weight 16 then most of the other elements have atomic weights which are very nearly whole numbers. Hydrogen is the noticeable exception which has an atomic weight 1.008. In the formation of helium of atomic weight 4, from hydrogen atoms, there is therefore a loss of mass of .008 or 0.8 of one per cent. of the hydrogen. Calculation shows that if our sun's energy is to be accounted for by the transformation of this matter into energy, and transformations of all other elements can probably be neglected in comparison, then it must be assumed that the whole of the sun was originally hydrogen. If it were so composed, its existence, past and future, can not exceed a hundred billion years. While this just about satisfies the time requirements imposed by other considerations, it is none too liberal. It has been argued that the stars are not hot enough to bring about the formation of helium

from hydrogen. The recent physical experiments compel us to believe, however, that somehow, somewhere this transformation has taken place and where, it has been asked, can one find a hotter place than in the stars.

On the third hypothesis, that of mass transformation, the time scale for the existence of the sun and stars is increased at least a hundred fold. The first evidence of the identity of matter and energy was suggested by the experiments of Sir J. J. Thomson in 1881. He showed that an electric charge in motion possesses inertia or mass due to that charge. Later, in the Kaufmann-Bucherer experiments, it was shown that the mass of an electron is proportional to its velocity, which leads directly to the conclusion that an electric charge at rest has no mass at all and hence matter and electricity in motion are identical. This conclusion is responsible for the frequent statement that all matter is electricity.

It would appear that the foundation for Einstein's hypothesis of identity of matter and energy was experimentally well established. While we have not been able to change matter to energy in any laboratory experiment there is no reason to believe that it does not take place under the conditions of enormous pressure, temperature and density which are found inside the stars. We may never be able to reproduce on earth these unusual conditions and it may be we are denied this privilege for our own protection. We must bear in mind that our world with all the diversity of conditions and life upon it is a most unnatural occurrence in the universe. Sir James Jeans says we should have to visit thousands of millions of stars before finding a planetary system as recent in creation as our own, and we should have to visit millions of millions of stars before finding a planet on which civilization is as recent a growth as that of the earth.

Before leaving the hypothesis of transformation of matter to energy it should be mentioned that there are some difficulties. Eddington, who is perhaps the strongest advocate of the theory, suggests that we should expect the greatest sources of heat to be in the newer stars and especially we should expect it where the gravitational density and temperature are highest. There are, however, so many contradictions and exceptions that no coordination can yet be seen. The theory can be treated only as a working hypothesis, a starting point for investigation.

A new and promising contribution to the whole problem of the origin of energy as well as an escape from the "Wärmetod" are the experiments of Professor Millikan at Pasadena. With zeal and insight which is characteristic of his work, Professor Millikan has for the past six years investigated the causes of the slow discharge of electroscopes which occurred in the earlier experiments of the Canadian physicists, Rutherford and McLennan. It was thought by the earlier observers that the leak of the electroscopes was caused by ionization of surrounding air which in turn could be traced to radioactive elements in the earth's surface. Millikan and his coworkers find that there is coming into the earth's atmosphere from outer space a penetrating radiation of the nature of x-rays or gamma rays. These are the so-called cosmic rays. These rays represent energy ten times as great as the hardest gamma rays of radium. They will penetrate a six-meter wall of lead and discharge the electroscope 70 meters under water. The beam of radiation has been shown to be composed of three principal frequencies. Now, as already stated, the work of Aston shows that the formation of heavy atomic weight elements out of lighter ones involves the loss of matter, and Einstein's theory shows that matter may be transformed into energy. Now

the cosmic ray frequencies coincide almost exactly with the theoretical frequencies derived by assuming the formation of helium and oxygen out of hydrogen and the formation of silicon and iron out of either hydrogen or helium, that is, the percentage loss of mass of hydrogen and helium is just sufficient to yield the observed wavelength when converted to energy, according to the theory.

There is support to this suggested upbuilding of the elements in the fact that the abundant elements in the meteorites, on the earth and in the stars, as revealed by the spectroscope, are just the elements whose formation could give rise to the three principal wave-lengths of the cosmic rays. Even the intensity of the band is greatest just where the Aston formation shows that greatest matter disappears and greatest amount of energy is thereby created. But there is present in the cosmic rays no extremely high frequency corresponding to the high intensity which would be incident to the formation of energy by the annihilation of electrons and protons.

Professor Millikan believes it is possible that waves of energy radiating away from the stars toward the boundaries of space may by some unknown process condense into electrons. There, where there is no pressure and no temperature, these charges may gravitate together to form hydrogen atoms. These in turn, like the molecules in the formation of crystals, may coalesce to form the heavier elements with the release of cosmic rays as a by-product. It is not difficult to imagine that the star dust may condense like water vapor into drops, to form the great star masses. These represent potential energy of mass separation. Thus the picture of the dissipation of energy and its reformation is complete. This inspiring bit of imagination is satisfying because it makes of the energy transformations of the universe a reversible cycle.

Since Einstein has made of the universe a closed system, it is to be expected that the energy transformations should be reversible. This greatest of nature's phenomena would involve a perfect reversible cycle and therefore a nullification of the second law of thermodynamics. It permits for the universe an escape from the "Wärmetod." While we see no way for a limited part of the universe like the earth to escape the "heat death" the universe as a whole may do so. Therefore to speak of the age of the universe has no meaning.

In conclusion, I should like to urge an attitude of liberality and openmindedness. There is much yet to prove, but quite likely the fingerpointing is in the right direction. Fanciful theories will disappear as soon as better ones are offered. We can make no progress in science if we are confronted by the fear of obstacles and criticism lurking around every corner. The century just passed was an age of materialism—perhaps too much materialism. Our scientific structure emerges out of a fantastic assemblage of failures and successes, in theory as well as experiment. No one could have predicted the unparalleled success in stimulating research and in correlating results which has come as a result of the almost reckless assumptions made by Einstein, Bohr, DeBroglie, Compton and the rest. If it be recklessness, I believe we are much farther in our quest for the truth because of the risk these men took.

For thirty years physicists have been engaged in analysis, analysis of radioactive products, of atoms, of protons, of the spectrum and so on. If Jeans and Eddington and Millikan want to work at synthesis and if in their process they overthrow our second law of thermodynamics in order to make of our universe a reversible cycle, who shall dispute their right?

RECENT TRENDS IN GEOGRAPHY

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GEOGRAPHY to the ancients included all studies of the earth and its life. It contrasted with astronomy, mathematics and philosophy. In time most of what the ancients included under geography was studied by specialists in only a portion of the vast field, and gradually became known by special names. Geography, therefore, became the "mother of the sciences."

The movement toward specialization became so great during the 19th century that many people thought that there was nothing left to geography but place geography and commercial geography. At any rate most of what was taught in American schools under the name of geography during the last half of the 19th century were facts as to the location of places, and as to the products exported. Many leaders of to-day, trained during that period or by people so educated, still think of geography thus narrowly, and for that reason it is often attacked by those who do not realize and appreciate its present status.

Geography has suffered, of course, by the loss of many scientific men who specialized and became known not as geographers but as geologists, anthropologists, physiographers, ecologists, climatologists, etc. It lost so much of its former prestige that it was scarcely taught in American universities at the end of the last century, and was not recognized as a distinct science by the National Academy of Sciences, or in Cattell's "American Men of Science."

During recent decades, however, it has won increasing recognition, first in Germany and France, and, especially since the world war, also in Britain and the United States. At present geography is taught in most universities, and there are scores of full professors of geography on the faculties, a number of universities having more than four. It is said that every university in Germany and Great Britain has a chair of geography, and nearly all of the larger American universities have departments of geography. Indeed Harvard and Clark have Schools of Geography. Recently, moreover, a geographer, Isaiah Bowman, director of the American Geographical Society of New York and author of "The New World," was elected to the National Academy of Sciences, the first man elected primarily for his work in human geography.

Geography has won this place because of the realization on the part of leading educators that it cultivates a field of knowledge well worth cultivating and not included in any other.

Geography has become far more than place geography and commercial geography, and now has several additional subdivisions, those of chief importance in universities being three phases of human geography, namely, economic geography, regional geography and historical geography. The study of plant and animal geography is, however, rather generally left to biologists, as there is an increasing tendency to restrict the courses given in departments of geography definitely to how the environment influences the life of people, in other words, to human ecology.

Geography's special field, the influence of the natural environment upon the nature and distribution of man's activities and qualities, places it between the natural and social sciences. As a result of its dual aspect, geography is classified as a social science in most French universities and in such universities as

Michigan, California, Minnesota and Ohio, but, on the other hand, it is classed as a natural science in most German universities and in several important American universities, including Wisconsin, Illinois, Princeton and Cornell. At Chicago, under the new grouping of departments, it is placed in both the social and the natural science groups.

Geography is well represented on the board of the *Social Science Abstracts*, the chairman of that board being a geographer. It is included, however, only incidentally in the great Encyclopedia of the Social Sciences, now being published in several volumes. The failure of sociologists to more generally recognize that geography has a significant contribution to make to the social science discipline is due to the incomplete development as yet of social geography.

Because of the fact that social geography depends not only on other phases of geography, but also upon history, sociology and economics, for much of its factual material, its later development is to be expected. As it gives promise of being of significant social value, it will be worth while to indicate some of its objectives, and something as to its limits.

Social geography is the study of how the environment influences people in considerable groups, not as individuals, families or corporations. It especially considers the variations in social ideals from place to place so far as their distribution is affected by environmental influences. Hence the shifting centers of civilization, and the rise and fall of communities and of nations are subjects of particular interest to the social geographer. Within a country the social geographer endeavors to discover what environmental influences help explain marked sectional differences in educational efficiency, in the production of significant contributions to civilization, in the social health, including criminality, and in the political influence of areas. A special phase is the study of the contrasts in the production of leaders of various kinds.

Social geography includes, therefore, certain parts of the fields of various other subdivisions of geography. Of economic geography, it includes the effects of the resources and their use upon the social life and ideals of the people, but it considers only incidentally, if at all, the phases of economic geography ordinarily studied, namely, the distribution and characteristic of the resources and the conditions affecting their utilization.

Of regional geography, social geography considers, to be sure, the contrasts among the larger regions in respect to topography, soil, climate and resources, but it especially considers the distribution of differences ordinarily ignored by the regional geographer, differences, for example, in the output of leaders, in the death rate, in the ownership of homes, in literacy—in brief, in the social forces of various kinds. Because of the often great local contrasts in conditions of social significance, the social geographer pays attention to even the lesser divisions of cities, towns and country, so far as they display significant contrasts in social ideals. Local differences, for example, in illiteracy, the birth rate, and in criminality are sought for by the social geographer who relates these differences so far as is practicable to geographic differences.

In the domain of historical geography, social geography is little concerned with the topics usually discussed, namely, the effects of the weather or of local topography or soil upon the outcome of a battle, or in the geography of territorial changes made in treaties of peace. Instead, social geography is concerned with the geographic influences that have effected the rise and fall of nations, the survival or elimination of racial types, the changes in ideals which have accompanied the migration of peoples, the spread of language or of politi-

cal influence, and the fuller utilization of resources.

Political geography is mostly a phase of social geography, although the social geographer leaves to the special student of political geography such topics as the details of the location of boundary lines and capitals.

This brief survey indicates the general scope of social geography. Its main objectives are to make full use of all available knowledge of the environment and its influences in order to more fully understand the customs, attitudes, and actions of groups of people.

Its chief methods are three: A study of differences in the customs and attitudes or ideals of originally closely similar peoples who, by reason of migration or of local changes in the environment such as result from the exploitation of previously unused mineral wealth, now have different environments. A second great method is the study of geographic environments that are similar in most respects but are dissimilar in a few, in the effort to find the possible cause of the observed differences in the social structure. The third method is by studying some special social feature, such as the position of women, the conditions of hygiene, or the prevalence of labor disputes in numerous environments to see whether they are correlated with any special environmental condition. For example, the social geographer inquires whether the production of leaders who have more than local and temporary significance is especially associated with any type of climate such as a cool climate with considerable seasonal range, and frequent changes of weather.

With so vast and difficult a field, and with few qualified investigators to work it, little has yet been established. Nevertheless a few generalizations have been deduced. Some of those suggested by Ellsworth Huntington and the present writer may be summarized as illustrations of the problems with which social geography deals.

Hypotheses Advanced by Social Geographers

(1) Civilization advances rapidly only where climatic conditions are at least reasonably favorable. If transported into an unfavorable climate, civilization soon declines unless continually renewed from more fortunate regions. Therefore, if the people of the favored regions wish to maintain a high level of civilization in less favored regions, they must not only supply leaders and wealth in a single campaign, so to speak, but must continue to do so decade after decade.

(2) Democracy is interfered with by exceptionally fertile soil, and by other conditions under which a living may be easily won. In such places the land and other wealth, and hence the power, are normally concentrated in the hands of the few, while the bulk of the population remain in a relatively retarded condition. In somewhat less fertile or productive environments, on the contrary, there is a distinct tendency toward relative equality of wealth, education and power.

(3) Such quickly extracted natural resources as oil, coal, gold, and timber are socially detrimental to the community which extracts them, and are therefore social liabilities, not assets, to such areas.

(4) The utilization of natural resources depends primarily upon the characteristics of the people, especially on their energy and mechanical advancement, rather than upon the proximity of the resources. Most of the coal and oil, for example, are used at considerable distances from the places where found, while, conversely, little local use is made of coal or oil except in areas where other geographic conditions are sufficiently favorable so that the people are economically qualified to use them.

(5) Only a small fraction of the world's area produces any appreciable number of leaders in proportion to population. This is because the effective use

of talent requires an appreciative public, one which actively supports originality. Most of the world's people are hindered by the conditions under which they live from being able to effectively use and support most sorts of talent. Areas within which it is rather hard to make a living may, however, produce numerous leaders if the local social environment is favorable, and if the leaders are in demand in other areas readily reached.

(6) Only a small part of the world now has a good social environment, because in most places one or more of the essential elements is lacking. These elements include a good geographic environment, which among other characteristics has a climate cool enough and variable enough to stimulate mental activity, but with sufficient warmth and moisture to permit profitable agriculture. A good social and biologic heredity is also required, as are facilities for the exchange of ideas.

(7) Cities contain a much wider diversity of people and activities than do larger areas of comparable population not adjacent to cities. This is because cities afford more opportunities for people of diverse abilities to obtain a living.

(8) The contrasts in social ideals within a city or other limited area are often enormous. In general they correspond with the popular idea of the desirability of the district. Slight differences in elevation, effectiveness of transportation facilities, physiographic attractiveness, or leadership are often accompanied by marked differences in social ideals. This arises largely through a process of social selection whereby people of various types sort themselves out as residents of different geographic areas.

(9) In order fully to appreciate social attitudes, the effects of selection as well as of geographic environment must be adequately considered. As mobility increases, selection operates increasingly powerfully, leading to sharper and sharper contrasts among the local populations and hence in their ideals. For example, in an area where the population is growing rapidly by the inflow of people, the averages of enthusiasm, optimism, mental alertness and physical vigor are high. Correspondingly, commercial ability is exceptionally represented in commercial cities, intellectual activity in educational centers, and pessimism in places losing rank in population and influence, such as declining farming districts.

(10) Even the areas that are best for civilization in one or more respects, such as climate, suitability for diverse agriculture, industrial activity, and the exchange of goods and ideas, nevertheless lack considerable of being ideal, because perfection does not exist anywhere on the earth. Hence each area needs to be extensively supplemented from other areas. Any agency which facilitates a ready exchange of goods and ideas is fundamentally socially advantageous. Consequently it is extremely doubtful whether tariffs and taxes on the means of transportation and communication do as much good as harm.

It will be readily conceded that such working hypotheses as the foregoing are distinctly thought-provoking and hence highly educational to those prepared to consider them. If social geography effectively accumulates data by which such hypotheses as these are tested, it is a field of great social significance and merits encouragement, and increased study in our universities. If by accumulating data indicating their correctness, it can cause influential people to take due account of even a few such generalizations, it will exert a profound influence.

PROHIBITION AND THE STRAW BALLOT

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THIS is a presidential year. Astute political observers say that, more so than in any election for forty or fifty years, the outcome will depend upon policies rather than personalities. And among the policies that interest vitally the American electorate at the present time, prohibition stands in the front, possibly only second to the more obviously economic issues. It is of more than ordinary importance, therefore, to gauge the sentiment of the country concerning the continuance or the abandonment of prohibition as embodied in the eighteenth amendment to the Federal Constitution.

Attempts to gauge this sentiment by noting the fortunes of candidates to political offices who have announced publicly their stand with reference to prohibition confuse more than they enlighten, because of the inconsistencies revealed. A complete solution can be obtained only by referring the amendment again to the people, preferably to state conventions elected for that purpose. It is to be hoped that this method will ultimately be applied, and it appears not unlikely that it will be applied in the near future. But until then other means of obtaining the desired information must be used.

For this purpose the straw ballot has been resorted to by many agencies and with varied success, and, incidentally, with varying results, depending mainly upon the section of the country covered, or the class of people whose opinions have been canvassed. The most ambitious of these straw ballots and the most widely discussed have been the two polls sponsored by the *Literary Digest*, one in the spring of 1930 and one in the early months of the present year. In each case more than twenty million ballots were sent to all sections of the country, each state being circularized somewhat closely in proportion to its voting strength. And in each case less than twenty-five per cent. of the ballots mailed out were returned.

The general public interest in prohibition and the great political import being attached to the returns of the *Literary Digest* polls warrant a most complete analysis of the returns, and a much more searching criticism of their significance than has hitherto been accorded them. Discussions of the two polls have been concerned entirely with the face value of the returns, with no apparent suspicion that these may not truly represent the sentiment of the twenty million people to whom ballots were mailed. The limitations of the returns rest in the inherent weaknesses of the straw ballot.

The agencies sponsoring a straw ballot can contribute to its success only to a limited extent. They can circularize a large number of people. They can compile their mailing lists from people of all classes and occupations, residing in all parts of the country. They can apportion their ballots among these classes, occupations and sections somewhat in proportion to their voting strength. But when this is done, the game passes out of their hands. The extent to which the different classes, occupations and sections will respond is entirely beyond their control. In particular the extent to which those favoring one or the other side of the question at issue will respond is out of their hands entirely. The representative character of the returns with respect to the different classes and occupations of people and the different sections of the country can be judged if the

ballots are marked with this information. But the extent to which the "pros" and the "antis" have accepted the invitation to express their opinions can not be judged from any superficial examination of the returns, and yet the accurate interpretation of the returns will depend directly upon this point. If the incentive to vote is as strong for those of one opinion as for those of another, the poll can be interpreted at its face value, but if this is not the case, the returns may give a greatly distorted picture of popular sentiment.

The incentive to vote in such an amiable contest as a straw ballot, where no political issue is at stake, will depend upon the questions asked. If it is a presidential poll, there is no apparent reason why, under normal conditions, the urge to vote among the supporters of one candidate should be any different than that among the supporters of his opponent. The fact that such polls have predicted accurately the outcome of a subsequent presidential election indicates that the straw vote was in fact unbiassed and that the followers of the two candidates must have voted to very nearly the same extent.

But in a prohibition poll, under prevailing conditions at least, the situation seems quite different. Those favoring the *status quo* may very well feel complacent, with little inclination to express themselves in a ballot in which the *status quo* is not threatened or endangered. On the other hand, those dissatisfied with the Eighteenth Amendment are apparently laboring either under a feeling of personal injury, or under a conviction that by reason of this amendment the government is unwarrantably infringing on the personal liberty of its citizens; or they may be inspired by a horror of the official venality seemingly associated with prohibition enforcement, a horror of the apparently wide-spread evasion of it and a horror of the vice and crime it may appear to foster. These feelings surely are more articulate than a feeling of complacency and may well constitute a greater incentive to vote.

The question of biassed returns in a straw ballot occasioned by a difference in the incentive to vote among the "ayes" and the "nays" can be pursued beyond the stage of mere speculation. It can be settled definitely by comparing the proportions of ballots marked in favor of the proposition proposed, obtained from the different states, with the proportions of the ballots mailed out that have been returned. If those states favoring the proposition the most strongly are returning greater percentages of the mailed ballots than those states favoring it less strongly or opposing it, this is *prima facie* evidence of a biassed return, since the percentage of ballots returned in any state is a measure of the average incentive to vote in that locality.

In applying this principle to the prohibition poll of 1930, it should be remembered that three propositions were proposed, any one of which could be favored. A recipient of the ballot could vote for (1) repeal of the eighteenth amendment, (2) its continued enforcement, or (3) its modification to permit the sale of light wines and beers. Of the approximately five million ballots returned, 40.43 per cent. favored repeal, 30.46 per cent. favored enforcement, and 29.11 per cent. favored modification.

To test the existence of bias in the returns, the five million ballots have been divided into five groups, each containing approximately a million votes. The first group comprises the total returns from the six states showing the strongest expressed sentiment for repeal. The second group comprises the total returns of seven states ranking next in "wet" sentiment as just defined. The third group comprises the returns of nine states next in order, and the fourth and fifth groups comprise the returns from

twelve and fifteen states, respectively. The nature of the composite returns from these five groups of states is indicated by the average figures listed in Table 1.

It seems clear from this presentation of the returns that those localities furnishing a high percentage of "repeal" ballots also returned a high percentage of the ballots mailed to them, and *vice versa*. A graphic demonstration of this fact is given in Fig. 1. On the other hand, the higher the percentage of "enforcement" ballots among those returned, the lower the percentage of ballots returned from those mailed out. No apparent relation exists between the percentage of "modification" ballots and the percentage of ballots returned. These voters' ballots made up a fairly constant proportion of the returns from each group of states, averaging 29.1 per cent. A distinctly biassed return in the poll is thus evident, due to a much greater incentive to vote among those favoring repeal than among those favoring enforcement.

Now let us examine the picture of the returns given in Table 1. It seems evident that the circles representing the five groups of states are not scattered at random over the chart, but rather tend to arrange themselves, somewhat crudely it is true, along a curve. It is possible to determine the type of curve if one makes certain assumptions that seem reasonable from the returns themselves. These assumptions are, first, that except for local influences differing from state to state, the "wets" and "drys" were voting in certain fairly constant average proportions, the proportion of "wets" voting evidently being much greater than the proportion of "drys." The second assumption is that the "modificationists" are a mixed group, made up of a "wet" and a "dry" wing, and that the proportion of "moderate wets" and "moderate drys" in the modification group in different localities varies as the proportion of "wets" (for repeal) and "drys" (for enforcement) in those localities varies. Hence, the "modificationists" would vote in a proportion equal to the weighted average of the proportions in which the "wets" and "drys" of their respective localities are voting.

TABLE 1

THE RETURNS FROM THE LITERARY DIGEST PROHIBITION POLL OF 1930, GROUPED IN CLASSES OF ABOUT A MILLION VOTES, ACCORDING TO THE INDICATED SENTIMENT FOR REPEAL

Number of states grouped	Number of ballots returned	Per cent. of mailed ballots returned	Distribution of returned ballots		
			Per cent. for repeal	Per cent. for enforcement	Per cent. for modification
6	997,040	30.42	49.84	19.17	30.99
7	948,363	29.02	46.60	27.47	25.93
9	1,002,024	21.93	42.68	28.98	28.34
12	1,000,110	21.49	34.11	33.13	32.76
15	810,756	18.18	26.47	45.62	27.91

These assumptions, put into mathematical clothing, define the type of curve which the circles in Fig. 1 are attempting to follow. The curve is a hyperbola, but since there are many different kinds of hyperbolas, the particular kind that describes the returns of this poll must be determined from the returns themselves by a process of "fitting." When a man goes to the tailor for a suit of clothes to be made to order, he picks out the pattern or style first, but then the

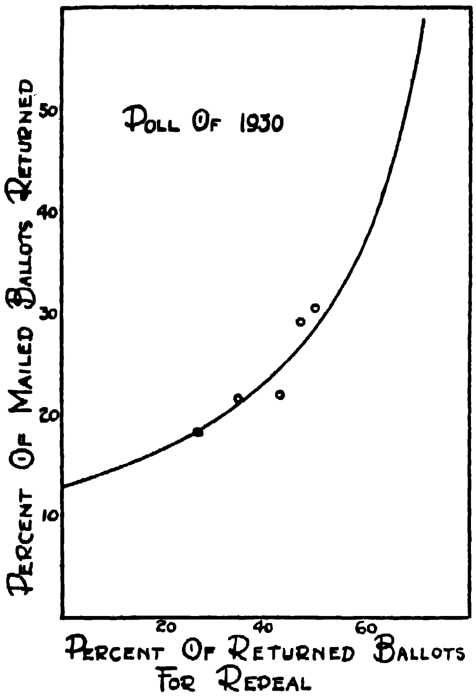

FIG. 1. EQUATION OF PREDICTION CURVE—

$$y = \frac{544.7}{41.90 - .461x}$$

y = per cent. of mailed ballots returned.
x = per cent. of returned ballots for repeal.

tailor must fit the pattern to his customer's own peculiar dimensions. Using this analogy, the pattern is a hyperbola and the tailoring consists in adapting the pattern to the situation at hand, though a mathematical pattern is much less flexible than a tailor's pattern, so that a perfect fit is only rarely obtained. The tailored curve is shown in Fig. 1; the fit is not a bad one.

We may now disregard the circles in the chart and reason from the curve, which tells us more clearly what the returns are trying to express. We see that when there are no ballots marked for repeal, the return of mailed ballots is only 13.0 per cent. This measures the extent to which the "drys" are voting. When no ballots are marked for enforcement, then 70.9 per cent. will be marked for repeal, the remaining 29.1 per cent. of returned ballots being marked for modification. The curve shows us that if 70.9 per cent. of the returned ballots are marked for repeal, 59.1 per cent. of all ballots mailed will be returned. This means that 59.1 per cent. of the "wets" are voting. The "modificationists," according to our premises, voted to varying degrees depending upon prevailing "wet" and "dry" sentiment in their localities. By an indirect calculation it appears that, on an average, they returned 22.6 per cent. of the ballots mailed to them.

If the "wets" voted to the extent of 59.1 per cent., the "drys" to the extent of 13.0 per cent., and the modificationists to the extent of 22.6 per cent., then the vote of the 20 million persons to whom ballots were sent, if they had all voted, can be readily predicted from the total numbers of ballots marked in the three ways. For the entire country it appears that only 16 per cent. of the 20 millions favored repeal, about 55 per cent. favored enforcement and about 29 per cent. occupied an intermediate ground.

The wide discrepancy between this prediction and the returns actually received represents the bias inflicted on the poll by the very nature of the questions asked. It illustrates the uncertainties of straw ballots, no matter how extensive they may be nor how fairly they are conducted and the returns compiled. When only a small fraction of the ballots mailed out are returned, the face value of the returns may be high, or they may be greatly misleading, as in the present case. Only a statistical analysis of them can tell whether they are of the first description or of the second.

In the second *Literary Digest* prohibition poll, just completed, the recipients of the mailed ballots were asked to express themselves on one proposition only, namely, whether or not they fa-

vored repeal of the eighteenth amendment. Again more than twenty million ballots were mailed out, of which less than five million were returned, a return of only 22.39 per cent. Of the returned ballots, 73.67 per cent. were marked for repeal and 26.33 per cent. were marked for continued enforcement. On their face the returns indicate an overwhelming sentiment for repeal, a proportion of about 3 to 1.

But before accepting this superficial verdict, it would be well to examine the returns for the same type of bias so evident in the returns of the preceding poll. If one compares for each state the percentage of returned ballots marked for repeal with the percentage of mailed ballots returned, no close correlation is evident. The irregularities are too great. However, one may divide the states into two classes, one class offering evidence of biassed returns and the other class offering no such evidence. The first class would include those states returning more than 22.39 per cent. of the ballots mailed to them and marking more than 73.67 per cent. of the returned ballots for repeal, as well as those states returning less than 22.39 per cent. of the mailed ballots and marking less than 73.67 per cent. of the returned ballots for repeal. The second class would include all states not falling under the two categories of class one. When such a division of states is made from computations based upon the published returns of the poll, it is found that thirty states offer evidence of bias, while nineteen do not.

For purposes of mathematical analysis, the returns have been divided into eight classes, depending upon the percentage of returned ballots marked for repeal. The first class includes all states for which 85 per cent. or more of the returned ballots favored repeal of the prohibition amendment. The next class includes all states for which from 80 to 85 per cent. of the ballots returned were marked for repeal. Succeeding classes are similarly defined, each class including a range of 5 in the percentage of "wet" ballots, except the last, which includes all states for which 55 per cent. or less of the returned ballots were recorded against prohibition. The relation between the percentage of mailed ballots returned and the percentage of returned ballots marked for repeal for the eight groups of states is pictured in Fig. 2. While much irregularity is evident, it appears that there is a distinct tendency for a high percentage of wet sentiment to be associated with a more complete return of mailed ballots and *vice versa*. This means a greater incentive to vote among the anti-prohibitionists than among the prohibitionists, a conclusion also deducible from the returns of the first poll.

In Fig. 2, we must again attempt to fit a curve to the circles representing the returns of the poll, but it is evident that a good fit can not be expected because of the irregularities evident. It is like the job a tailor would have in fitting a modish pattern for a suit of clothes to the hunchback of Notre Dame. The hyperbola pattern will not bend itself around the irregularities. The fitted curve shows, however, the same

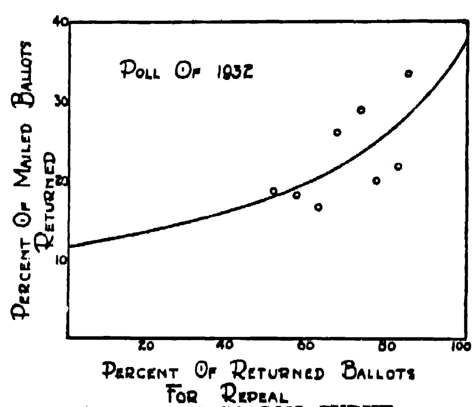

FIG. 2. PREDICTION CURVE—

$$y=\frac{434.7}{37.70-.262x}.$$

y = per cent. of mailed ballots returned.
x = per cent. of returned ballots for repeal.

downward swing from right to left as do the actual returns, and it threads its way through the circles in a manner indicating as close an agreement between fact and theory as could be expected. The curve predicts that, among those favoring repeal, 37.7 per cent. returned the ballots mailed to them, while among those opposed to repeal only 11.5 per cent. marked and returned their ballots. These values, together with the numbers of returned ballots marked in the two ways, lead to the conclusion that only 46 per cent. of the twenty million people to whom ballots were sent favored repeal of the eighteenth amendment, instead of 73.7 per cent., as indicated on the face value of the returns.

In summarizing this analysis of the two prohibition polls, it is interesting to inquire to what extent they are consistent and to what extent they indicate a shift in sentiment on the question. It is significant that the estimated incentive to vote among those favoring enforcement of the amendment in the first poll and among those opposing repeal of the amendment in the second poll is very nearly the same, as measured by the estimated percentage return of their ballots, namely, 13.0 as against 11.5. This agreement would indicate that the complection of this group has not changed. On the other hand, the incentive to vote among those favoring repeal was much greater in the first poll than in the second, as measured by an estimated return of 59.1 per cent. of mailed ballots against 37.7 per cent. The complection of this group has evidently changed in such a way that the incentive to vote has been greatly reduced. In the first poll there was a third group of dissenters, favoring modification of the eighteenth amendment to permit the sale of light wines and beers. How did this group vote in the second poll? If their disagreement with prohibition became more intense in the two-year interim, or if, merely because they were denied the privilege of expressing their more moderate views, they preferred repeal rather than continuance of a condition with which they were dissatisfied, they would align themselves with those who all along had intensely favored doing away with prohibition entirely. Being less intense in their dissatisfaction, however, their incentive to vote would be less and their amalgamation with the "repealers" would lower the average percentage of mailed ballots returned for this group in the second poll, somewhat as the percentage actually was lowered from 59.1 to 37.7.[1] That such a regrouping actually occurred, perhaps with no marked change in sentiment toward prohibition, receives some confirmation from the fact that in the first poll, 55 per cent. of all people canvassed appeared to favor continued enforcement, while in the second poll 54 per cent. of all people canvassed were against repeal. Again this group seems a stable one. The 16 per cent. of outright "repealers" and the 29 per cent. of modificationists in the first poll apparently combined forces in the second poll.

The present situation appears to be this, if one may assume that the twenty million people on the mailing lists represent the entire country. Approximately half of the population are steadfastly opposed to repeal of the eighteenth amendment, while approximately half favor repeal if no other course is open. A minority of the latter half are steadfastly in favor of repeal, while a clear majority would probably be satisfied, either with a modification of the amendment to permit the sale of the less intoxicating liquors, or with a modification of the enforcement laws leading to essentially the same result.

[1] In fact, if the voting percentages of the "repealers," 59.1, and of the "modificationists," 22.6, in the first poll are weighted by the relative strengths of these groups, 16 and 29 respectively, and averaged, the result is 35.6, not greatly different from 37.7, the voting percentage of "repealers" in the second poll.

SCIENCE SERVICE RADIO TALKS

PRESENTED OVER THE COLUMBIA BROADCASTING SYSTEM

ELECTRICITY, THE MODERN HANDMAID OF CHEMISTRY

By Dr. COLIN G. FINK

HEAD, DIVISION OF ELECTROCHEMISTRY, COLUMBIA UNIVERSITY

THE science and art of chemistry had its beginnings many thousand years ago. Thus, such chemical products as soap, glass, paper and porcelain were known to the ancients, and the knowledge of manufacturing these and other products was handed down from generation to generation. Who was the inventor of soap—one of the most important of chemical products? His name and origin have long since been forgotten. Through the ages up to as recently as 1800, there were but slight changes in process of manufacture of soap and many other chemical products. New and valuable articles were added from time to time, but the basic methods of preparation and manufacture remained inherently the same. With the close of the eighteenth century, however, the classical discoveries of Galvani and of Volta opened to the chemist an entirely new field of attack. Chemical products could be made or decomposed by electricity. The epoch-making discoveries of Galvani and Volta in Italy stimulated research throughout Europe, and within a few years Michael Faraday, of England, announced to the world his discoveries of the intimate interrelation between electrical and chemical phenomena. By the middle of the nineteenth century the comparatively limited supply of electricity from the Volta battery was infinitely increased through the invention and perfection of the electric dynamo—a machine that converted readily available, mechanical power into electrical energy.

After the appearance of the electric dynamo, the greatest forward step in chemistry and chemical manufacture took place: not only were old processes—cumbersome and costly—discarded, and new, electrical, clean and simple processes substituted therefor, but a host of new products were discovered. New metals, such as sodium, magnesium and aluminum, never before known to man, were extracted with the aid of electricity from familiar salts. Chlorine gas, which is the underlying basis of our bleaching industry, was formerly made by a very lengthy and wasteful chemical process. Now, by merely passing an electric current through water in which ordinary table salt is dissolved, tons of this yellowish-green gas are produced, and so easily and cheaply that the industry is forever turning out more chlorine than is consumed by the public. And this very electrical, or electrochemical, process, which produces chlorine gas at one pole, produces caustic or lye at the other pole, simultaneously. This caustic or lye is mixed with animal fats and made into soap.

In 1892, Thomas Willson, an American, mixed ordinary marble with coal and passed a strong electric current through the mixture. He obtained a new "stone" or compound, calcium carbide. Returning from lunch on the day of his discovery, it started to rain, and the rain-drops coming in contact with his new product caused a hissing sound and a powerful gas—acetylene—was evolved. This day marked the birth of

one of the foremost of chemical industries—calcium carbide, acetylene, hydrocyanic gas, acetone, acetic acid, solvents, etc.

In 1891, Edward Goodrich Acheson, one of our foremost pioneers in electrochemistry, passed electricity through coal and converted it into graphite—a most valuable lubricant—better and purer than any natural graphite theretofore produced. No lubricant other than Acheson graphite will stand the temperatures developed in our modern super-high-speed bearings. In another experiment Dr. Acheson powdered ordinary coal and mixed it with Coney Island sand, adding a little salt as seasoning. He then sent a powerful current of electricity through this mixture —so powerful that the sand was changed into gas—and the result of the experiment was a new product—carborundum—which you use to sharpen your carving knife or your razor blade.

Many of the chemical plants at this time were expanding, and new ones were being erected in different parts of the country. From the smoke-stacks of these factories thick fumes and often acids belched forth which ruined trees and other vegetation, not to mention the discomforts brought upon people working or living in the vicinity of these factories. F. G. Cottrell suspended a chain through the center of these smoke-stacks, applied a high voltage current and lo, and behold, no fume, no dust any longer came out of the stacks, just as though the factories had shut down completely. But, of course, they had not. Electricity was causing those myriads of smoke and fume particles to go down instead of up. And more than this: the dust was collected and in many cases was found to contain valuable constituents, such as silver. This Cottrell process is so simple that many factories, such as fertilizer factories, instead of avoiding smoke, find it to their advantage to first convert their products into fume or smoke and then pass electricity through the smoke and throw down or precipitate the fine particles subsequently converted into high-grade baking powder and other products.

The ancients knew how to apply gold coatings to baser metals, such as bronze and copper, but the process was tedious and uncertain. The gold had to be first hammered or beaten out into very thin sheets, a process that often took several days to complete. The sheet or gold leaf obtained usually had many holes and other imperfections. This leaf was then mechanically fastened to the surface of the bronze or copper and the bond or union was never very secure, so that the slightest knock or scratch would loosen the leaf. To-day the article, such as jewelry made of base metals, is suspended into water containing a little gold dissolved in it. Electricity is passed through the water, and almost instantly the brooch or ring or other article is completely covered with a resplendent coat of our most noble metal, gold. The coating is uniform and thoroughly adherent. And gold is not the only metal that is now plated over other metals by electricity. Silver, nickel, zinc, lead, copper, tin and chromium are similarly plated to-day. Without electricity your car would have no chromium plate.

Iron is one of the oldest and most serviceable of metals. Yet nearly everything that was ever made of iron by our forefathers has long since turned to rust and disappeared. Only a few rare specimens have been preserved and handed down to us. It is this tendency for iron and steel to rust that has for years stimulated investigations in all civilized countries of the world, with the hope of making iron and steel rust-proof. Here, again, electricity has been the immediate means toward a solution of the problem. By mixing iron with

other metals, notably chromium, and passing powerful electric currents through these mixtures, iron alloys have been produced, such as stainless steel and the chromium-nickel alloy that covers the Chrysler Building, which defy rust and deterioration for all time to come.

Many more examples fully as startling as those cited could be recorded and suggestions might be offered as to electrochemical discoveries and inventions of the future. To mention but a few, we need new products and processes to convert our super-heavy railway equipment into such that will excel that of the modern airplane. We need a chemical machine that will convert the boundless energy of the sun—most of which is wasted to-day—directly into electricity, instead of first converting a mere fraction of sun energy into trees and trees into coal, and coal into heat and heat into steam and steam into electricity. We want to apply electricity to different substances and change these substances easily and rapidly into a food as valuable as milk and as cheap and abundant as spring-water. We want to produce by electrical and chemical means materials harder than diamond and much cheaper than gems, to produce metals lighter than aluminum and stronger than steel, electric lamps ten times as efficient as the best tungsten lamp of to-day, to produce dyes that never fade, and silver that does not tarnish. The investigator in chemistry to-day is indeed fortunate to be able to apply electrical methods in seeking a solution of these and many other important problems.

SCIENCE IN FOOD PRODUCTION

By Dr. RAYMOND A. PEARSON

PRESIDENT OF THE UNIVERSITY OF MARYLAND AND CHAIRMAN OF THE EXECUTIVE COMMITTEE OF THE ASSOCIATION OF LAND GRANT COLLEGES AND UNIVERSITIES

IT has been said that the science of yesterday is the commonplace of to-day. We need only to look about us to realize the truth of this saying. Good roads are being laid in every part of our country by thousands of men who know how to do the mechanical work, but seldom do they or the rest of us who use the roads stop to think about the scientific studies that made these roads possible. Electric lights are almost universal in thickly populated communities, and they are becoming common in rural districts. Almost every one knows something about the use of electricity, but seldom do we think of the years of investigation that were necessary to make it available. I might enumerate many other such examples, but they will occur to you. Most of us realize how important are the results of scientific research and we are glad to see this kind of work promoted.

To-day we are to talk about the results of research in food production or agriculture. Science has been finding its way rapidly into this great field of work, and now it can be said that every important agricultural operation is dependent upon or is closely related to certain definite scientific studies that have been completed or are in progress.

A few years ago soil hunger manifested itself, and the yield and quality of crops suffered accordingly. Some soils were wearing out. That problem was finally mastered, temporarily at least, by new knowledge of plant foods which was made available by scientific studies. Now every good farmer knows

how to take care of soil hunger by the proper selection of his crops and by cultivation and by the use of fertilizers. Unfortunately, that problem hardly had been solved before we realized that another soil problem, soil erosion, is just as serious or worse. Literally millions of tons of our best producing soils, which required thousands of years to build, are being carried away by the rivers to the sea. Thousands of acres of good land have vanished. Areas that have been highly productive are now useless. With an increasing population and a larger demand for food, it is evident that something must be done. When the soil was not plowed and cultivated, there was comparatively little erosion, but plowing and cultivating are necessities of civilization. The soil scientists are studying this problem and are making progress.

About 30 years ago the cattle raisers in certain sections of the country were suffering enormous losses from a disease that affected a large proportion of their animals. It was transmitted easily and occurred year after year, in spite of well-known preventive measures. The losses mounted into the hundreds of millions of dollars. Finally a few veterinary surgeons and bacteriologists discovered that the cattle tick was the carrier. With this definite information, and assistance from the zoologists, the disease is being rapidly eradicated. Hog cholera almost threatened to destroy the hog-raising industry until scientific studies showed how it can be avoided or controlled by sanitation and the use of serum.

Years ago it was comparatively easy to raise potatoes. Then, from somewhere, the potato bugs arrived. They killed millions of potato plants and ruined many a farmer's potato crop. The entomologists found methods of controlling these pests, but now we have another potato affliction—the potato blight. Scientific men have told us how to deal with that, too. Successful potato growers have to understand many problems of this kind. And the same is true of producers of other farm products, both in the animal and plant kingdoms.

Questions relating to food production are national questions. They interest everybody, because everybody must eat. And so the Federal Government years ago provided for an agricultural experiment station in every state, in connection with the agricultural colleges. Most of these stations now receive from their own states larger appropriations than from the Federal Government. Also, the Federal Government has provided for research work in the Department of Agriculture at Washington. So there is a great organization of workers in agricultural science. Their relation to the farmers of the country is the same as the relation of scientific men, maintained by big industrial organizations, to those industries. Of course, the public pays for the industrial research indirectly. It pays directly for agricultural research through taxes and appropriations. This is because every person is concerned and because agriculture has no enormous commercial units representing hundreds of millions of dollars that can afford to maintain expensive scientific studies.

There is one important difference between science in its relation to food production and in its relation to most manufacturing operations. Agriculture has more surprise problems, and often these threaten whole crops or herds so they must be dealt with promptly and vigorously. I suspect that manufacturing industries do not require nearly as much emergency research as does agriculture.

It costs about $18,000,000 a year to maintain the state experiment stations, but only about $13,500,000 of this comes from the taxpayers, and about $17,000,000 a year to maintain the research work in the Federal Department

of Agriculture. About 1,800 people give full time to the work in the state stations and a larger number give part time, and there are about 4,000 people in the federal agricultural research work. This may sound like a costly luxury. But, let me say quickly that in comparison with what we spend for food, these expenditures to safeguard the nation's food supply are exceedingly small and even trifling.

I wish there were time to tell you about more of the notable achievements of workers in agricultural science and of the direct importance of all this to every citizen. I can mention only one or two. Some recent discoveries are still novel and therefore interesting to the majority of people. For example, the Japanese beetle has appeared in this country in recent years. When it once gets into a locality, it increases in number with amazing rapidity. It has an enormous appetite for growing plants of many kinds. Various methods of controlling this pest are being studied, but one is unique. Scientific men discovered that this particular beetle is attracted by an odor somewhat like that of the rose geranium, so they developed in the laboratory a substance that has this odor and they are using it as bait for traps to catch the beetles. The geranium aroma is carried by the breezes over a wide area. The beetles in this area fly towards the trap, hoping to get a good meal. They are captured by the gallon and sometimes by the bushel. About 600 barrels, not bushels, of Japanese beetles have been caught this year in a heavily infested area in one of the Eastern states. Think of the food crops they would have destroyed! Let us hope that the entomologists some day will find a bait that will rid the country of mosquitoes! Of course, we know that much has been done already in controlling them by putting oil on the marshes and ponds where they breed. But I have been in places where I thought there must be a few gallons of adult, hungry mosquitoes that ought to be caught for the benefit of suffering humanity.

I would not have you understand that all these scientific discoveries are made by experts, for they are not. Many of them are credited to farmers who had the faculty of observing unusual conditions and of putting two and two together. For example, there was the farmer in France, who, like every other grape-grower, had become familiar with Bordeaux mixture as a remedy to protect grapes. This French farmer noticed that when the spray fell on a mustard weed, it killed that weed, although it seemed to have no effect on other kinds of plants. A spray to kill a troublesome weed was a new idea, but now it has become fairly common for mustard. Sprays for other weeds are being developed by research workers. I wonder if the time will come when weeds will have their numbers and druggists will have the remedies under corresponding numbers, so that anybody can get rid of any weed with the aid of a prescription that he can write himself, such as remedy No. 113 for weed No. 113. Such an achievement may be no more impossible than many of the developments in science appeared a short time before their accomplishment. How happy the hay fever victim would be if some such remedy as I have mentioned could be applied to ragweed! Probably it will come, in time.

Let me emphasize that it is the public —all the people—who are the chief beneficiaries from scientific studies relating to food. The benefits come, to be sure, through the efforts of farmers who apply the knowledge. It may seem remarkable, but it is true, that farmers do not possess trade secrets, and they do not amass fortunes by taking advantage

of scientific work to reduce their cost of production or to protect their crops and animals from destruction. They pass on the advantage to the consumers. If wheat growers could be shown how to cut the production cost of wheat five cents a bushel, then the consumers would get their wheat that much cheaper. Farmers may have their faults. Who does not? But they never have been accused of hoarding, nor of monopolizing. Those practices are not possible in American agriculture.

Summarizing, then, in closing: Research in agriculture is necessary, not only to improve standard agricultural methods but especially to enable farmers to contend with new diseases and pests that have a way of appearing unexpectedly and that may become highly destructive to our food supply. Because of the wide interest in agricultural problems and the dependence of everybody upon their successful solution, the Federal and State Governments have seen fit to support research work. And lastly, the benefits which come from the application of science to food production are passed along promptly to the ultimate consumers.

THE MEDICAL CARE OF ANIMALS IN THE ZOO

By Dr. W. REID BLAIR

DIRECTOR AND GENERAL CURATOR, NEW YORK ZOOLOGICAL PARK

In order to maintain a large collection of wild animals in a state of good health it is necessary to provide suitable sanitary buildings, a wholesome and hygienic food supply and expert medical supervision. In order to successfully combat diseases, especially those of a contagious nature, a most complete and efficient quarantine system is absolutely necessary. A grave form of disease may be introduced by apparently mild or trivial cases. With animals arriving almost daily from different parts of the globe, great care must be constantly exercised in guarding against the introduction of a possibly diseased animal into a collection known to be healthy.

Prevention of disease is the constant aim of the medical department. All sanitary measures contribute to the healthfulness of our animal collections. Disinfection as a preventive of disease plays no insignificant part in the medical work of the Zoological Park. Among the Zoo's charges are some of the rarest and most valuable specimens in the world, and it goes without saying that the death of any one of them would be a great blow to the scientific world, not to mention the serious financial loss entailed, even if it were possible to replace them.

In a zoological park with collections as large as ours, sickness, accidents and death must inevitably occur. Animals are subject to almost as many of the ordinary ills as is man, and in captivity these ills are frequently intensified. The difficulty in arriving at a true diagnosis is greater in wild animals than in the domestic species. Where docility is a pronounced factor, one arrives at a diagnosis by a process of elimination, by the use of the thermometer, the pulse, tapping and listening to the chest cavity, and otherwise handling the patient without undue excitement. While the human patient can tell you his feelings in their regular order we can only infer most of these in the animal through external manifestation of pain and dis-

comfort. The wild animal physician must carefully watch for and accurately observe all such symptoms, and then endeavor to rightly interpret them.

If, in addition to all the obstacles in the way of treating these patients, it is realized that wild animals in captivity are subject to nearly all the diseases common to man and the domestic animals, and that every wild animal is well equipped with claws, horns, sharp teeth or tusks, and with a strength and agility far beyond that of a human being, you may get some idea of the difficulties with which the wild animal physician must contend.

One advantage the animal doctor has over the human practitioner is that he does not have to listen to long tales of imaginary ailments from his patients, nor do they just fill themselves up with patent medicines before coming to the doctor as a last resort. Unfortunately, the "patent medicine man" has not yet appeared with a panacea for all ailments to which wild animals are heir.

When an animal is ill it is, if practicable, removed from its fellows, whether its disease is contagious or not. In the former case the reason is obvious, but in all cases quietness and extra comfort are needed. The patient can be better observed, the symptoms more closely noted, and the disease from which it suffers more clearly defined when the animal is alone and left to the exercise of its own undisturbed will.

To provide for the treatment of diseases and for the operations which are necessary where a large number of animals are kept in captivity, it is essential that hospital accommodations be provided. The New York Zoological Park has a well-equipped hospital. There is probably no other hospital where such a varied list of patients might be seen. The hospital is conveniently located near the center of the park and well isolated within a walled enclosure, which insures quiet. It is a large, single-story brick building, containing medical and surgical wards, operating room, pharmacy, diet kitchen, quarantine room, research laboratory and the doctor's office and study. All the wards are equipped with sanitary cages. Electric exhaust fans, which can be regulated to insure a perfect system of heating and ventilation, are installed here.

In giving medicine to wild animals it is necessary to concentrate the drugs as much as possible. It is best that the animal should not know that it is getting medicine at all, so that it becomes necessary to disguise the drug in some way. For the practitioner of human medicine modern pharmacy has provided a large number of preparations, which in some respects are even more necessary to the animal physician who ministers to sick animals which can not understand the object of what must seem to them ill usage.

Again, there is every reason why the animals should get their medicine in the way that will cause the least disturbance to their feelings and without that excitement which may follow a struggle to give medicines. Small pills, gelatine or sugar-coated, sweet lozenges, tablets or capsules, carefully concealed in an innocent-looking banana, may be administered to an unsuspecting ape, without the slightest difficulty. Occasionally, however, he may suspect, and great is your dismay at seeing him minutely pick the banana apart, find the offending pill, test it with his teeth, smell of it, and finally with a wry face cast it through the bars of his cage at his keeper.

The nursing of sick animals is of the greatest importance. The essentials are pure air, sunlight, cleanliness, warmth and nourishing and sustaining diet. During convalescence all kinds of delicacies are offered to tempt the appetite, first one thing and then another; but no

food is allowed to remain long before the animal, because the very fact of its being constantly present will cause him to loathe it. When the animal has no appetite it may indicate that the stomach is not in a proper condition to digest food; consequently, if forced upon him it will cause indigestion and aggravate the case.

While digestive and pulmonary diseases are the more common ailments requiring medical attention, yet the doctor is frequently called upon to perform major and minor surgical operations. If the operation is painful, a general anesthetic is administered, because in addition to the humane sentiment involved perfect control of the animal is necessary for the safety of the operators and also for the successful handling of the patient. Chloroform and ether are used for general anesthesia, with local injections of cocaine or morphine in minor operations.

Some of the surgical operations that are performed from time to time are unique. Once our African rhinoceros, "Victoria," required a surgical operation for a deep-seated abscess which affected the lower jaw-bone. The rhinoceros was hobbled with ropes, cast upon a grass mattress and put to sleep with chloroform. While less than an ounce of chloroform will send a human being to sleep, it took two pounds of chloroform and three quarters of a pound of ether to put this animal in a state of pleasant slumberland and render the operation entirely painless.

It is not a simple matter to prepare a big alligator for an operation, and when "Big Mose" had to be operated on for a large tumor on his foot, it was like handling a well-lubricated pig. In preparing Mose for the operating table his head was covered with a gunnysack, then his jaws were muzzled, and he was securely fastened with strong ropes to a thick plank eighteen inches wide and twelve feet long. Local anesthetics rendered the removal of the tumor a painless procedure.

Some of the most difficult animals to control are the larger lions and tigers. A full-grown lioness, captured by the late "Buffalo" Jones, was noted upon her arrival to have some injury to her front feet. While she sulked and would not permit any examination, close observation detected the trouble to be that the claws had grown into the pads of her feet, making it necessary to destroy the nails. Getting this ferocious animal to an operating table was a real problem. However, the Lion House is very well equipped for all sorts of emergencies, and one of its modern improvements is an elevator with a fixed cage six feet long and two feet wide. Meat was placed in this cage, and the lioness was enticed into it. Once the lioness was trapped, a tarpaulin was placed over the cage, making it airtight. She was quickly chloroformed by means of an atomizer pump, roped and securely tied. The operation of removing the irritating claws was a matter of but a few minutes' work. The lioness' cage was then wheeled out of doors and she promptly came to. And what a racket she made! She roared and howled! The whole park resounded with her rage and anger. Visitors ran up, but one look was enough. The lioness plunged to the front of the cage, and though she had no chance to get loose, that crowd made for the exits without delay. The animal was well in about ten days and lived in the park for more than fifteen years, a good age for a lioness in captivity.

Bears also need plenty of surgical attention. Once one of our huge Alaska brown bears, while engaged in a fight, drove one of his canine teeth (two inches long) completely through his upper lip. The animal was wild with pain until he was chloroformed and the lip released by means of strong forceps.

It would make a charming commentary on our work if we could note any gratitude on the part of our patients for what we do for them. As a matter of fact, we rarely see any notable response of appreciation. I recall an orang-utan that was once treated for pneumonia and later became a thorough hospital addict. He was constantly looking for attention and was very agreeable about being treated for any ailment.

An unusual operation on animals, though it is not uncommon on humans, was performed on the eye of our Indian rhinoceros "Mogul." This rare animal, a splendid physical specimen, came to the Zoological Park with a cataract in each eye, causing blindness. It was necessary to perform the delicate needling operation in which a knife is inserted in the eyeball and the capsule of the lens is ruptured in order to dilute and permit the absorption of the opacity.

The operation is absolutely painless and is often performed on human patients without a general anesthetic, but with the rhinoceros it was necessary to place the animal under chloroform as well as to use cocaine on the eyeballs. The surgery was the easiest part. Preparing the patient for the operation was far harder. The animal weighed nearly two tons and had such big feet and short legs that it was a difficult matter to get him on the operating mattress. It required the united efforts of ten keepers to hobble and cast him. After two operations the animal was able to see.

DAY-DREAMS

By Dr. EDWIN G. FLEMMING

NEW YORK, N. Y.

No great work has ever been accomplished but that it had long before been achieved in the dreams of the doer. But in dreams there is danger as well as the seed of great deeds.

When desires are unsatisfied they are not eliminated from the sphere of influence in our lives. We continue to desire, we spend more or less of our time in wishing. And when there is even a lingering hope of securing our desires we continue to strive. The unsatisfied desire, kept alive by imagination and hope, then serves as the mainspring of effort.

But an interesting and important fact is that even when there is no hope of accomplishing our desires we still continue to dream about them. All of us have day-dreams in which we experience the possession of things that we do not possess, or in which we accomplish things to which we have not yet attained. We do not dream about things we have but about things we do not have. We do not dream about things which are easy to get but about things which we apparently can not get.

Ordinarily, when, through dreaming about things, we see a way which appears within our ability to achieve we are likely to attempt some kind of overt activity in order to secure our desires. But many people do not clearly see the means by which they can make their dreams come true. That is especially true of children; and if the child's day-dreaming habits are not wisely handled he may be unlucky enough to have the habit become fixed, so that through the rest of his life he is content with dreaming instead of attempting to do.

When the day-dream is serviceable to the individual we are inclined to say he has a good imagination or a very fertile mind. It is when imagining things appears to be an end in itself instead of a means to an end that we say the individual is a dreamer and visionary. The doer dreams just as much as the dreamer, but the doer is not content with his dreams.

Day-dreams first appear when something has gone wrong, when there is a discrepancy between desires and reality, when a person can not actually get what he wants, or when he gets what he does not want in the form of punishment. The child then wishes that things might be different, and wishing them different makes them different for the child mind. Day-dreams are then used as compensation for actual lacks in real life.

Such imaginings are pleasant to the child because he is the center of the dream in which everything happens as he "thinks" it ought to happen. Finding such imaginings pleasant the child begins to indulge in imaginative play, and may after a time find that such imaginative play is more satisfying than real play. For instance, a little boy—an only child—wanted a dog. The parents for one reason or another did not want a dog. The boy began to imagine that he had a dog. The particular, imaginary dog followed him home one day, a fact that he called to the attention of his grandmother as she was coming home from a shopping trip with him. The youngster dawdled along behind and had to be hurried every few minutes. Finally he said he couldn't hurry because his dog wouldn't mind. The grandmother indulged him and finally got him and the dog safely home after

a number of adventures. At home he took care of the dog as if it were a real dog.

There are other cases in which children create imaginary playmates who are the nicest children imaginable, always doing what their creator wants them to do. One little girl created during the course of a few years a whole world of people, a step at a time, in which she was the queen.[1]

The fact that the day-dream is used as a means of satisfying thwarted desires is of importance and it is likewise noteworthy that in the day-dream the dreamer occupies the central, exalted position. Where that does not happen in the beginning the dreamer very soon identifies himself with the central character of the dream. Such was the case in the development of the day-dream of the girl who had a whole world subservient to her wishes. At first she just had an imaginary playmate who could do the things the dreamer wanted done. When the playmates increased into a family, then a nation, and finally a world, the original imaginary playmate was their queen. But soon the dreamer identified herself with the imaginary queen and at last became queen herself.

Such dreaming is not in and of itself bad, but it is always indicative of some lack in the life of the youngster. If the lack continues and the child, through the development of the dreaming habit, comes to substitute dreaming for reality then there is danger. At first the dreamer recognizes that the dream does not represent reality, and the dreamer may pass from the dream state to reality at will. It is then that day-dreaming often takes the form of imaginative play. For instance, a little boy, who was removed from his usual environment in which he had several sisters with whom to play, found himself almost alone with only another boy about his own age as a playmate. The new playmate was stronger than he, and made him do things that frequently he did not want to do. The new playmate was boss, as it were, whereas with his sisters, who were all considerably older than himself, he was petted and catered to in everything. The child began to play having company. The visitors were always young ladies, who came to talk to him about parties and good things to eat. He talked to them about the things he had been doing or imagined he had been doing, sang for them, and treated them with imaginary ice cream and cake.

Playing house and school or playing storekeeper are of this same kind of imaginative play, in which the creator of the situation takes the dominating rôle and moves the creatures of his imagination about at will to do his bidding. Here the child identifies himself with the adults who, he has observed, have power to control the actions of others. Thus the child satisfies his repressed desire to be the central figure in his universe.

An interesting case of identifying oneself with the masterful is that of a boy, physically weak, who in his day-dreaming play became a general of whom he had read. He played with lead soldiers by the hour, moving them about and controlling them as he had never been able to control his playmates. He also had the habit of identifying himself with the characters about whom he read in fiction and history and added to the stories the things he wanted to happen. These dreams were so real to him that in school one day he put himself into a difficult position and maintained it with great vehemence against the prevailing opinion of the rest of the class.[2]

Not infrequently parents, whose own dreams and ambitions for themselves have remained unrealized and unrealiz-

[1] See George H. Green, "Psychanalysis in the Classroom," pp. 33 *ff*. G. P. Putnam's Sons, New York, 1922.

[2] See Caroline B. Zachary, "Personality Adjustments of School Children," Chapter I. Charles Scribner's Sons, New York, 1929.

able, dream dreams of accomplishment and success for their children. All too frequently such ambitions for one's children lead to difficulties for the children. When the dreams of the parents are unsuited to the talents and abilities of the child, the child is often forced and driven beyond his capacity, with the result that there is sure to be failure and the development of feelings of inferiority. Such day-dreaming parents do not check up their ambitions for their children with the facts of reality, and many a good merchant is spoiled to make an unsuccessful doctor or lawyer or preacher. Deans of men and women in colleges, teachers and principals of schools are all too familiar with the difficulties of the boy and girl whose parents are still day-dreaming and attempting to satisfy those dreams through the medium of the activities and accomplishments of children who would be better citizens, more successful in their careers and happier and more pleasant personalities if left to themselves to develop the talents and interests which they actually possess.

Day-dreaming and imaginative play of the day-dreaming type may in some cases go to such an extent that the individual tends to shut out reality and to take the dream for actuality. One boy had dreamed so much and often that he was a great inventor that he actually came to believe that he was a mechanical genius. As a child he was interested in all sorts of mechanical toys and devices. He dreamed that he was a great mechanical engineer. He "planned" all kinds of wonderful devices and became enormously wealthy as a result of his inventions. He explained his inventions to his father and to his uncle, who became convinced that the boy had unusual ability and would one day become a famous man. But he was never moved to work out any of his inventions on paper nor in the form of models. He was content with the dream.

He came to college heralded as an embryo mechanical genius. The professor of physics found very soon that he did not know the first thing about the elementary concepts of physics. And what was worse, he would not apply himself to learn them. Digging facts out of a physics text-book was hard work—much harder than dreaming great inventions. Some of the things he "invented" indicated an acute observation of mechanical needs. He talked over the problems with engineers and architects whenever he had a sympathetic audience, and it appears that some of his ideas showed a knowledge of general mechanical principles. But he had no knowledge of details, and less patience than knowledge.

One invention of which he had thought he was urged to work out in detail. He played around with the idea for a while and did make a crude drawing which, however, was of no service. He was then urged to make a model, which he promised to do immediately. But before he had started on the model he communicated with a patent attorney, or said he had, and said that the attorney pronounced the idea good. The attorney was going to make a search of the patent records to see if the idea was patentable. In the meantime he reported difficulties in getting materials for the model. He said he had written for them, but the house from which he had ordered the necessary items was slow in sending them. For almost a year he talked about his invention as if it were already an accomplished fact. He saw himself sought by Edison to be given a special training in order that Edison might have some one ready to take his place when he passed into the Beyond.

Later the boy transferred to another college where he thought he would be better understood and would have

greater opportunity to secure the training that would develop his great ability. After one term he left that institution and secured a position as an apprentice in a large manufacturing plant where he was sure the practical training would give him the opportunities that he could not find in an academic environment where the emphasis was too much upon the theoretical.

This boy had indulged so much in day-dreaming and had been unwisely encouraged to be satisfied with mere dreams instead of, at an earlier age, having been stimulated to translate dreams into realities that for some time to come he is bound to suffer from his inability to face things as they actually are. He will, in his own mind, be misunderstood by his fellows. If he has any real stamina, and through hard knocks, piled one upon another, is forced finally to look at the world and himself as it and he are, he may achieve something.

From shutting out reality it is only a short step to the process of abstraction in which the dreamer appears to be entirely oblivious to everything about him and wholly absorbed in his own thoughts. The absent-mindedness of the scholar is similar to the abstraction of the dreamer. The absent-minded professor, however, is more likely to be thinking about some troublesome problem in connection with a research project, or is working out a close argument for a lecture, or is mulling over some abstract concept of his particular specialty; he is not so likely to be imagining himself in an exalted position receiving the plaudits of the multitude or accepting honors from some scientific or philosophical society. To be sure, the absent-minded shut out reality and are abstracted; but the day-dreamer who is abstracted has gotten to that stage where, for the time being at least, it is as if the thing he is imagining is actually happening. One young man, for example, used to dream that he was speaking before audiences of thousands of people, holding them spellbound. While walking through the woods or alone along the open road he would deliver his oration as if before the packed amphitheater. His abstraction was such that he was at those sublime moments no longer himself but the great orator. When brought back to reality by some trifling incident he was conscious of the fact that he had been day-dreaming; but during the dream he was unmindful of everything and unconscious of the fact that the great occasion was not real. There was a slight tendency later to feel that the great orator was the real self.

If such abstraction should proceed further, as it does in pathological cases, one of two things may happen, depending upon other contributing factors. Either the individual becomes so convinced that he is the great Mogul and consequently incapacitated to carry on the normal activities of life that he is diagnosed as insane and sent to a hospital for the mentally ill; or he may develop an alternating personality. At one time he may be his normal self, with no knowledge of the other abstracted individual and his glorious experiences; and at another time he may be the individual he has dreamed of being, who likewise has no knowledge of the normal self. The realities of life may bring with them such emotional conflicts that the personality is split, the second personality living an existence that avoids the complications confronting the real personality.

A case in which the individual had gone to the ultimate extreme in identification and abstraction is that of an orphan girl who constantly imagined herself as a person in a very superior position. Just before she was committed to a hospital she sent for a reporter and told him a long story of her success in singing the leading part in Tosca. She explained to him that through some unfairness on the part of one of the opera

company she was forced to live in poverty.[3]

And so the mechanism of day-dreaming is invoked, all unconsciously, in order to bring the individual those satisfactions that are denied him in reality. Emotions and desires may be thwarted and repressed, but generally the organism finds some way of getting around the thwarting influences, often being satisfied with mere day-dreams.

In conclusion we would emphasize the fact that day-dreams are not necessarily a baneful influence in the efforts of the individual to adjust to the realities of life. They may in fact be the very basis for great achievement. The danger enters when one is satisfied with the shadow in the dream and makes no attempt to actualize the dream content. For parents and teachers and others who are concerned with assisting the young to make satisfactory and satisfying adjustments to the manifold problems of living, the caution should be registered not to attempt to eliminate day-dreaming, since such a procedure would only serve to drive the child further within himself. He would not cease to day-dream, but would merely refrain from telling about his day-dreams to the person who would repress them. The day-dream represents a real lack in the life of the dreamer. The proper procedure, consequently, is to inquire into the nature of the lack and to encourage the person actually to do something toward the realization of his dream.

[3] See Caroline B. Zachary, "Personality Adjustments of School Children," pp. 54, 55. Charles Scribner's Sons, New York, 1929.

CHANGING FAMILY SITUATIONS IN A SMALL COMMUNITY

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I

During 1931 a study of a small Middle Western community was completed. The study was unique in that the ethnographic technique was exclusively used. The major purposes were to accurately record the old culture which preceded the introduction of machines, and to record the reactions of the culture as a whole to the new situation brought about by the change in its material aspects.

In order to study the latter phenomena it was deemed advisable to choose a community which was comparatively free from the economic crises so dominant in industrial cities. The community chosen was one entirely dependent upon agriculture, but which was not isolated from urban culture. Other variables were likewise ruled out. The following brief description will suffice to make this clear.

Shellrock, Iowa, the community chosen, is in a rich agricultural area located about thirty miles from Waterloo, an industrial city of about sixty thousand inhabitants. It consists of a village center, which has averaged a population of 811 since 1885. During that time it has not varied more than fifty from that average. The country included in the community consists of a population of about 1,600. The entire wealth of the community comes from the surrounding farm land.

The town was founded in 1857, and by 1885 it had nearly reached its maximum size. It was founded largely by old American stock of the Protestant faith whose various sects are still em-

braced by the present citizens. Shellrock has never experienced an influx of foreign blood. In fact, only a very small percentage of new blood of any kind has come in since 1890. Moreover, both the commercial and agricultural groups have the same cultural and social origins. The two groups are not hostile to each other, but participate equally in the same social activities. Such a community can not in any way be called typical, and no such claim is made.

A third purpose was to initiate a social study which would approach the nature of a controlled experiment. Unlike the chemist, the social scientist is not able to set up an experiment but must content himself with describing the social phenomena resulting from existing combinations of variables. If the social scientist, however, studies one group and clearly defines the variables, he may later follow up with the study of another situation which may differ in only one variable from the first. For instance, the above items have been noted in the Shellrock complex. Now if we follow this study by one of another community which is similar to the first except, let us say, in racial composition, it should be possible to note crudely the influence of the racial factor in combination with a specific complex. This method, although less accurate, would approach that of the controlled experiment in the physical sciences.

II

The newspaper files, as well as any other available written material, were read, but they were one of the minor sources of information. The most information, especially that concerning the fundamental attitudes, standards and evaluations of the people, was obtained from the old residents who are still living. Direct questioning of informants brought questionable results. The best information was gained through listening to the group conversations of the people, and participating with them in their group activities.

The questioning method was completely abandoned. Although the questionnaire easily lends itself to quantitative study, it is likely to reveal rationalizations rather than actual fundamental attitudes. Participation and observation results in more accurate information.

After the complete record of the community activities was concluded, an analysis of the family situations was made. A portion of that analysis follows.

The most outstanding thing was the interrelationship between the family organization and the other social phenomena. One large section of the study was devoted to the family. In that chapter was a great mass of material on economic and other social life. Likewise, all the other chapters contained important material on the family situations. It would have been impossible to accurately record or understand the family situations if they were isolated from the entire social and economic complex. This close relationship will be still more emphasized by the points which follow.

Life in the country, with the existing economic and social traditions, demands the united efforts of a man and woman. Agriculture represents one of the most primitive industries of man, and, consequently, retains more of the primitive traits of social organization than the more recently evolved industries of manufacturing, found in the urban areas. No provisions, for example, were made in the organization of agriculture to accommodate the single man or woman. The tradition of certain work for men, as distinguished from other work for women, is still strong in the rural areas. The family is the economic unit of farming.

Women's work is largely limited to the care of the house and the minor indus-

tries of the farm. Among the latter is included the care of the garden. In Shellrock, the division of labor incident to plant culture corresponds with the world-wide pattern of woman as the horticulturalist, while man appears in the rôle of agriculturalist.

In the case of the dominant woman who can make her husband take part in the gardening, the latter usually plants the seeds in the corn rows, and, rather than hoe it, he plows it with the corn cultivator.

With regard to the division of income, the general rule of the community is that the income from all major activities of the farm belongs to the man, while the income from minor activities conducted by the wife belongs to her. This is well illustrated by poultry raising. Under the old system the woman cared for the chickens and received the money acquired from the sale of eggs and surplus roosters. With this money she financed the household. Since the introduction of the coal or oil hover type brooder, and custom hatching, chicken raising has become less tedious and uncertain and the financial returns greatly increased. With this change in the financial importance of poultry raising the men have taken it over and the income no longer belongs to the women.

Other changes in material culture have reduced woman's work. Formerly, all the bread, as well as cake, cookies, pie and other pastries used by the family, was baked by the housewife. A large portion of the vegetables and meat were canned, dried or cured by the wife for use during the winters. The family used to be practically self-sufficient. As late as 1912 the worst thing that could be said regarding the shiftlessness of a family was, "They live out of a tin can and paper sack." It was only the lower classes who lived in that way, but now the trait has percolated upward to all classes.

This increased dependence upon the outside world has raised the cost of living. The increased cost of the necessities, plus the increased number of luxuries desired as the result of advertising, has resulted in a decrease in the number of children per family. In three generations the average number of children has dropped from six to two per family. From talks with men in the harvest fields and conferences with women one is given the impression, and often told openly, that children are accidents. Four children are considered an indecently large number, and usually only ne'er-do-wells have such large families. Birth control is taken as a matter of fact and is not even considered a debatable matter.

When asked why they do not have more children they plead economic pressure. This economic pressure, however, results from the desire for luxuries, such as automatic refrigerators, automobiles and electric light-plants. Not infrequently one hears a woman remark as she looks enviously at a new automatic refrigerator, "We were going to get one, but now that we had the baby we must give it up, one has to give up so much for their children."

Children, moreover, are a greater social liability now than formerly. Since the shift away from home-made recreation there is no place for the small child or pregnant woman. Pregnancy is discussed as if it were a disease, and the pregnant woman is "pitied" by her friends. Often one hears such remarks as "Poor Mary, she feels so badly about having another baby."

The child no longer has an important place in the family. With the increased importance of education his contribution to the economic process has been reduced to a minimum, while his needs have become a greater strain upon the family finances.

The shift to commercialized entertainment has made recreation become an individual rather than a family activity.

This not only weakens the family, but is a source of internal friction. While the family was the unit of entertainment the control of the young group was comparatively simple, for they were under the surveillance of the elders. The automobile and the individualization of recreation take the young people out of the range of adult supervision.

The automobile has become an indispensable tool of courtship. As yet the family is not organized to meet the problem presented, and a great deal of conflict results. Each boy is certain that his family, out of sheer perversity, will not permit him the use of the car, and his parents are equally sure that "he doesn't care if we get to go anywhere or not." Both sincerely believe the other to be selfish. The boys seldom get the machine until after much coaxing and many temper tantrums on both sides. Because the boy never knows when he will get the car the "dates" are made "on the spot" rather than in advance.

Neither the parents nor children know how to cope with the problem. The elders look to the past as their guide, while the children face the immediate problem and get their way through any tactics. The most pitiful conversations overheard are those in which a group of parents stimulate each other with tales of how thoroughly they uphold the established group sanctions in their families. For a few moments, away from the actual dilemma, they play the part of bold champions of the old order. A check, however, shows that they are only play acting.

Another force operating to weaken the family is the lack of economic opportunity for the young people within the community. This lack of opportunity causes the youth to look toward the outer world. The community attitudes reflect the recognition of this scarcity. The parents expect their children to leave home upon graduation from high school. The community as a whole expects them to leave. In the opinion of the community going to the city is a step toward success. To remain at home after graduation is considered an indication of lack of worth. The boy who remains in Shellrock and takes over his father's business and runs it successfully does not enjoy the prestige of his classmate who leaves town and is fairly successful in the city.

III

In conclusion we may say that the ethnographic study of Shellrock gave four important results.

First: The family situation can not be studied alone but must be analyzed in its cultural matrix.

Second: Primitive characteristics of organization are retained until new material traits are introduced. Then there is a breakdown of the organization and an aimless groping after another form.

Third: The introduction of our new material culture has weakened group organizations, and, temporarily at least, strengthened individualism.

Fourth: The family ties are being severely strained by the new material culture and the social results incident thereto.

ACTION OF A RUNNING HORSE

By Dr. EDWIN H. HALL

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In the Scientific Monthly for December, 1931, I spoke of a drawing made by Clerk-Maxwell as a boy of eleven years, reproduced here as Fig. 1, saying that it showed an astonishing perception of a horse's action in running, and I contrasted this drawing with the conventional representation of running horses in the sporting prints of Maxwell's boyhood. Two such representations are shown in Figs. 2[1] and 3. It will be noted that every horse shown in these two pictures, which are fairly typical of the ordinary prints of their time, has his forelegs reaching far forward and his hind legs reaching far backward, in a rocking-horse attitude. Instantaneous photographs, which of course were unknown when these prints were made, rarely if ever show a running horse in this position. The fact probably is that the unaided eye of the ordinary spectator notes each pair of legs in its most extended position, because that is the simplest position and perhaps the one of least rapid change of aspect. It fails to note that the extension of the forelegs is not, as a rule, simultaneous with the extension of the hind legs. Every horse shown in Fig. 3 seems in danger of dragging his hind feet on the ground at the next instant and incurring some rupture of his anatomy in consequence.

[1] Figs. 2, 3 and 4 are taken from Nevill's "Old English Sporting Books."

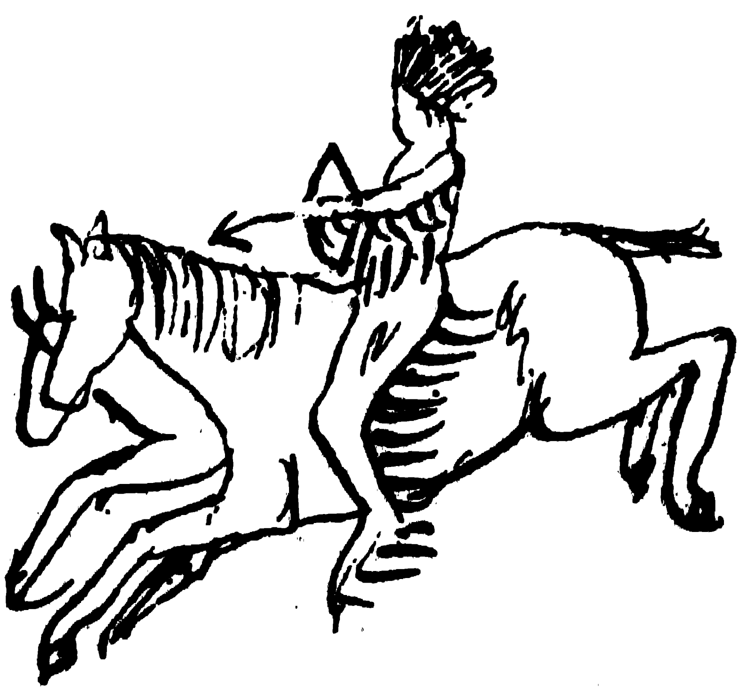


FIG. 1. A SKETCH MADE BY MAXWELL WHEN HE WAS ELEVEN YEARS OLD

FIG. 2. ILLUSTRATION FROM "ANNALS OF SPORTING" VOL. III, 1823
ENGRAVED BY THOMAS SUTHERLAND AFTER SAMUEL ALKEN.
(By courtesy of Messrs. T. Rimell & Son.)

Muybridge's instantaneous photographs[2] of a running horse show a decidedly complicated action of the legs. It appears that the horse studied, after his flight with all four feet off the ground, lands first with one hind foot (say the left), then with the right hind foot, then with the left forefoot, then with the right forefoot. Muybridge calls this gait a "cross gallop." Some animals after the flight land with a different one-two-three-four order of the feet. Cats and racing dogs land on the forefeet, then bring the hind feet far forward and leap almost wholly with the hind legs.

A leaping horse, in clearing an obstacle, takes off and lands very much as a cat or a racing dog does in plain swift running. The early part of a horse's leaping flight is well shown in Fig. 4, evidently not a photograph. Clerk-Maxwell's sketch, Fig. 1, shows a somewhat later stage of the leaping flight, rather than an aspect of the plain run, if Muybridge's photographs show the only type of action in such a run. How veracious Fig. 1 is, for a leaping flight at least, can be seen by comparing it joint by joint with Fig. 5, an instantaneous photograph of a horse in flight over a hedge.

A great many years ago I read a thrilling short story of a cross-country race, in Ireland, between an American horse named Choolook, carrying an American rider, and an English horse named Inkerman, carrying an Englishman, the prize being, of course, the hand of an Irish lady. The writer of the story, who seemed to know all about horses, spoke well of Inkerman. Inkerman was a good horse under a gallant rider. "Inkerman could run," but Choolook could and did "run like a cat," landing from his flight on his forefeet; and, said the author, the horse that runs in this way need never fear the

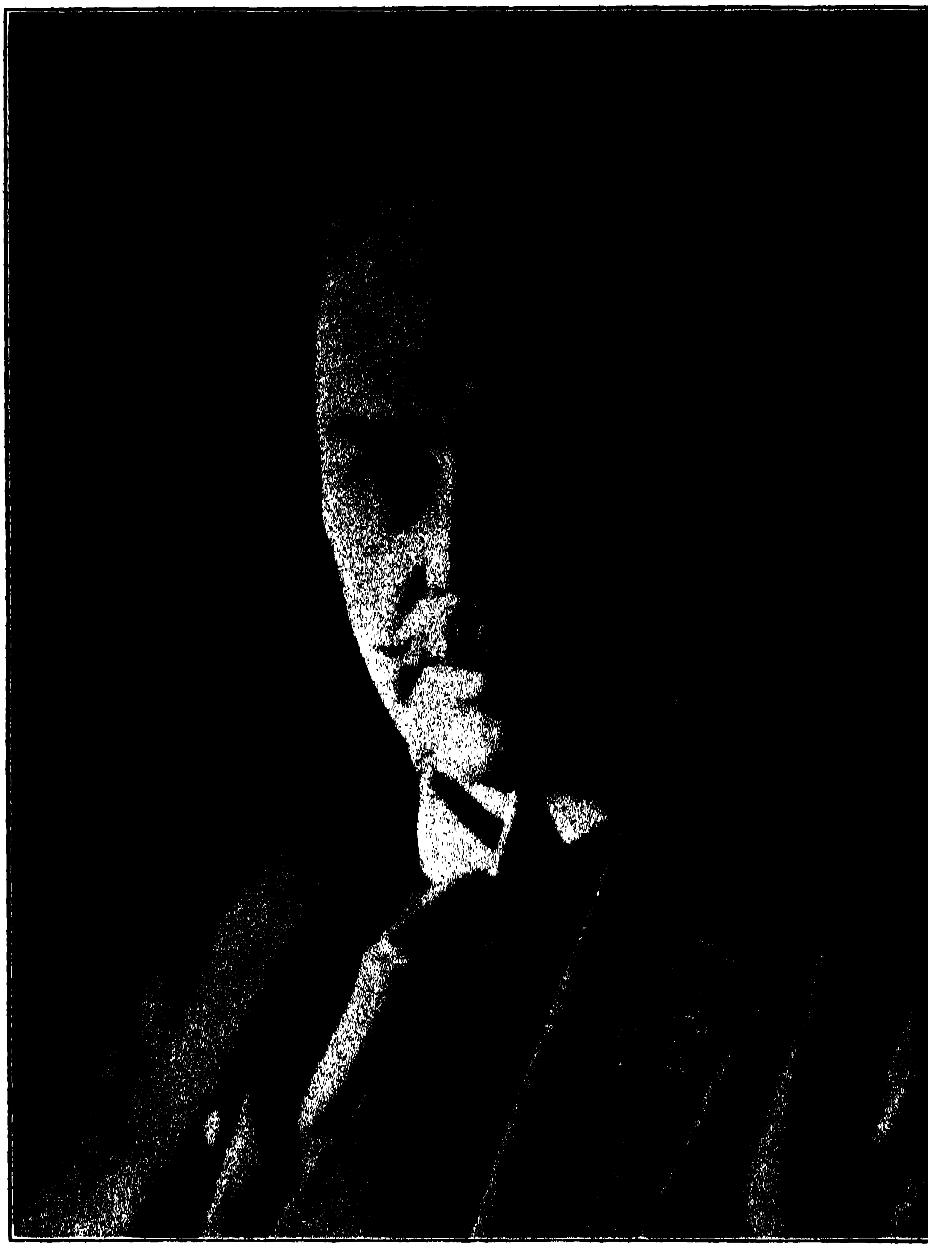
[2] "Animal Locomotion," Vol. 9, to be looked for in the Fine Arts Department of large public libraries. Published in 1887 under the auspices of the University of Pennsylvania. See also Muybridge's "Animals in Locomotion," London, Chapman and Hall, 1899.

FIG. 3. ASCOT RACES

FIG. 4. ILLUSTRATION BY W. T. MAUD
FROM "HAWBUCH GRANGE" BY THE AUTHOR OF "HANDLEY CROSS," ETC. 1847 EDITION.
(By courtesy of G. de A. Lopes, Esq.)

FIG. 5. UP AND OVER

horse that does not. So for nearly sixty years I have supposed that I knew the gait of the super running horse to be the same as the gait of a running cat; but a recent study of Muybridge's photographs leaves me wondering. Was my convincing story-writer wrong or did Muybridge generalize from the photographic study of too few horses? Is Man-o'-War or Gallant Fox, for example, an instance of the horse that runs like a cat, or is there no such animal?



SIR RONALD ROSS

WITH HIS DEATH ON SEPTEMBER 16 AT THE AGE OF SEVENTY-FIVE YEARS, THE WORLD HAS LOST ONE OF THE GREAT KNIGHTS OF MODERN SCIENCE. HIS WORK ON THE CAUSE AND CONTROL OF MALARIA WON FOR HIM THE NOBEL PRIZE IN 1902.

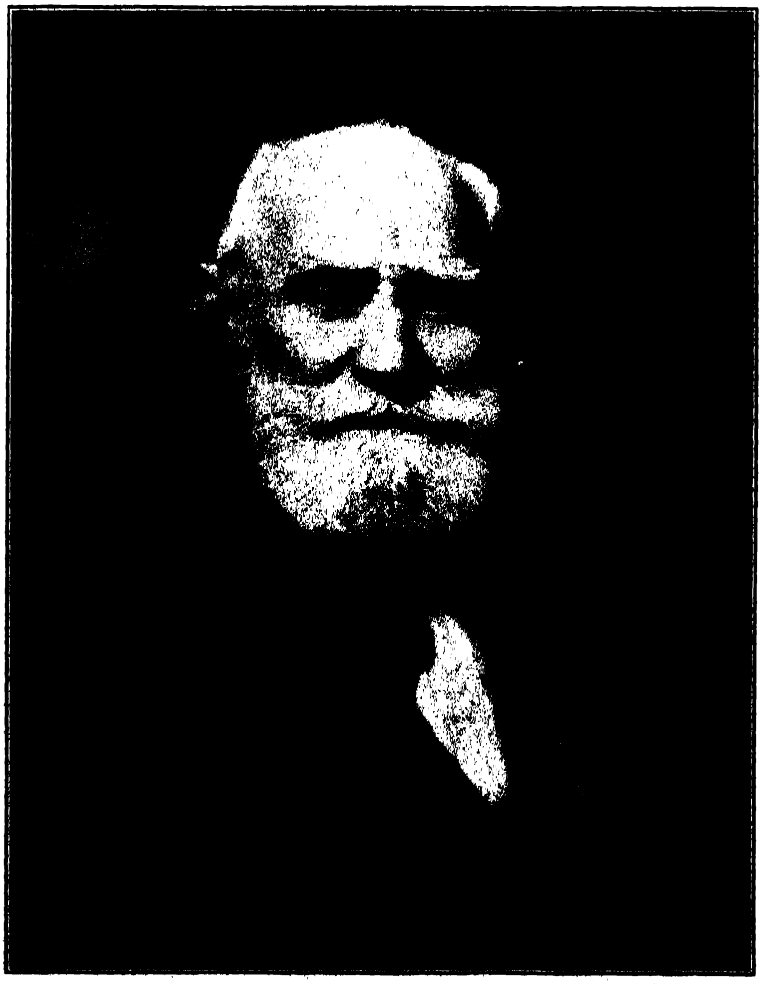
THE PROGRESS OF SCIENCE

THE INTERNATIONAL CONGRESSES OF PHYSIOLOGY AND PSYCHOLOGY

THREE years ago the International Congresses of Physiology and Psychology met in the United States—the physiologists at Harvard University and the psychologists at Yale University. Now the congresses have again met, this time widely apart—the physiologists at Rome and the psychologists at Copenhagen.

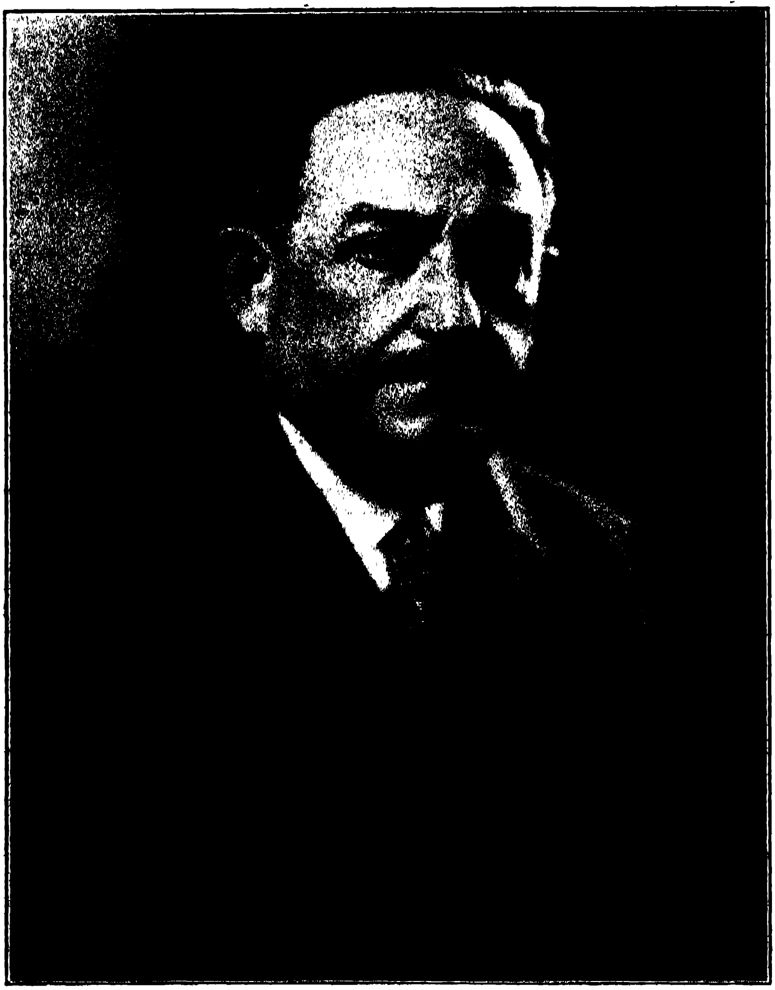
The Quirinal and the Vatican united to make welcome the Fourteenth International Congress of Physiology, which met at the beginning of September. Premier Mussolini presided over the opening session; and the members of the Congress were later received in audience by Pope Pius XI.

The Congress was held under the presidency of Professor Filippo Bot-



PROFESSOR IVAN P. PAVLOV

AT THE MEETING OF THE FOURTEENTH INTERNATIONAL CONGRESS OF PHYSIOLOGY IN ROME, PROFESSOR PAVLOV WAS ELECTED TO THE PRESIDENCY OF THE CONGRESS WHICH WILL MEET IN RUSSIA IN 1935.



PROFESSOR FILIPPO BOTTAZZI
OF THE UNIVERSITY OF NAPLES, UNDER WHOSE PRESIDENCY THE INTERNATIONAL CONGRESS OF PHYSIOLOGY WAS HELD.

tazzi, of the University of Naples. The principal address was given by Professor A. V. Hill, of University College, London, who spoke on the physiology of muscular action. Another address of outstanding interest was given by Professor Ivan P. Pavlov, who celebrated his eighty-third birthday on September 26. He had also the week before addressed the psychologists at Copenhagen. Among the papers read in the sectional meetings was a series on the chemistry of muscular contraction.

The United States was well represented at the Congress, with a delegation of about one hundred, including Dr. W. H. Howell, president of the preceding Congress. The next International Congress of Physiology will be held in Russia in the summer of 1935, under the presidency of Professor Pavlov.

The psychologists decided to meet in Copenhagen largely to do honor to Professor Harald Höffding, one of the leaders in the foundation of modern psychology, who, however, died at the age

HARALD HÖFFDING
WHOSE DEATH PREVENTED HIM FROM FILLING THE OFFICE OF PRESIDENT OF THE TENTH INTERNATIONAL CONGRESS OF PSYCHOLOGY.

of eighty-eight years before the time of the meeting. Professor Edgar Rubin, of the University of Copenhagen, was chosen to succeed him.

The King of Denmark presided at the opening exercises, and there were numerous receptions and entertainments, such as can be provided to special advantage at Copenhagen or Stockholm—perhaps the two most civilized cities in the world. One of the receptions was held in the beautiful house and park given to the Danish Academy of Sciences as a residence for one of its distinguished members. It had been occupied by Professor Höffding and is now assigned to Professor Niels Bohr.

The scientific program included 157 papers, and there were about 500 members in attendance, 98 of these from America, including Dr. J. McKeen Cattell, president of the preceding Congress; Dr. C. E. Seashore, chairman of the delegation appointed by the United States Government, and Dr. W. R. Miles, president of the American Psychological Association. The next Congress is to be held four years hence in Madrid under the presidency of Professor L. Myra, of the University of Barcelona.

THE ITHACA MEETING OF THE AMERICAN PSYCHOLOGICAL ASSOCIATION

BINARY fission is recommended as a possible remedy for the ills of the body of psychology, at present pulled two ways between the introspectionists of the classical school and the modern disciples of the experimental method. Dr. Robert M. Yerkes, of Yale University, made this suggestion of an amicable bill of self-divorcement before the meeting of the American Psychological Association at Ithaca. He would classify the two sub-disciplines of the science of psychology respectively as psychology and psychobiology.

Children learn the "right" colors for a picture at a very early age, it was indicated by experiments reported by Dr. Ada Hart Arlitt and Pessa Polasky, of the Pre-School Laboratory of the University of Cincinnati. They showed their young subjects twenty masterpieces of art, first in their original colors and then colored in violation of the laws of color harmony. Increasing numbers of the children preferred the original masterpieces. The children, however, showed no choice between primitive pictures and examples of modern art dealing with the same subjects.

When a baby and an infant ape of the same age are brought up together, the more rapidly maturing simian at first outstrips its human companion in learning manipulative processes, Dr. W. N. Kellogg, of Indiana University, stated. The superiority of the ape was probably due in large measure to its strictly human environment, he believes.

A similar experiment performed by Dr. Louis W. Gellermann, of Yale University, however, brought out evidence that even at an early age the young human can outreason the young ape. In coordination tests with geometrical figures, with food as a reward, two babies learned the right marks more quickly than did two young chimpanzees. The chatter of the babies as they puzzled over the boxes showed that they learn not alone by trial and error but by thinking out the problem in words. This superior ability to verbalize distinguishes the mentality of human beings from that of apes, Dr. Gellermann believes.

Contrary to the glib and hasty popular generalization that "at sixteen you are as intelligent as you are ever going to be," Dr. Louis D. Hartson, of Oberlin College, found that upper classmen in college surpass entering freshmen in the performance of standard psychological tests. In only one subject, arithmetic, did the younger student excel. As might have been expected, students about to graduate made the highest scores in the general subjects in which they had "majored."

Ten-point type with two-point leading, such as is used in the SCIENTIFIC MONTHLY, is most readable, tests reported by Dr. Miles A. Tinker, of the University of Minnesota, indicate. Any of the "orthodox" type faces make for easy reading, but "freak" types slow the reader down and let his attention wander. The ideal length for a line printed in ten-point type, Dr. Tinker said, is three and one third inches. Type with only a single lead between the lines is no better than type set solid.

Parents and mental hygienists differ regarding what constitutes bad behavior in a child, Dr. Ralph M. Stogdill, of Ohio State University, discovered by questioning a considerable number of both classes. Parents in general regarded as reprehensible conduct that contravenes conventional standards, such as disobedience and violation of social taboos. Hygienists were more concerned over things that operate to the disadvantage of the individual himself, such as bashfulness and day-dreaming.

Performance taught under the stimulus of rewards is learned at a rate in proportion to the promptness with which the reward is given, Dr. John B. Wolfe,

of the University of Illinois, learned in experiments with albino rats. Delays of 5 and 30 seconds, and of 1, 2½, 5, 10 and 20 minutes were used with trials of no delay for comparative purposes.

Most animals used in psychobiological tests learn their way through a maze most rapidly when a reward of food awaits them. Not so with ants, however; they learn the maze most rapidly when they are on their way back home with a prize they have found. Tests with these unusual subjects were reported by Dr. T. C. Schneirla, of New York University.

Electric currents, even though they have the same form and frequency as sound waves, do not serve in the same way as a stimulus to the auditory nerve, Dr. George Kreezer reported. The relation between the electric currents which accompany the nervous impulse from the ear to the brain and the sound waves which produce the stimulus have long been under investigation. The auditory currents, it has been stated, have the same form and frequency as the sound waves. In Dr. Kreezer's experiment, cats were conditioned to expect food when they heard a certain sound. Then an electric current of the same form and frequency was applied to the auditory nerve. Contrary to the expectations of the experimenter, the animal did not respond.

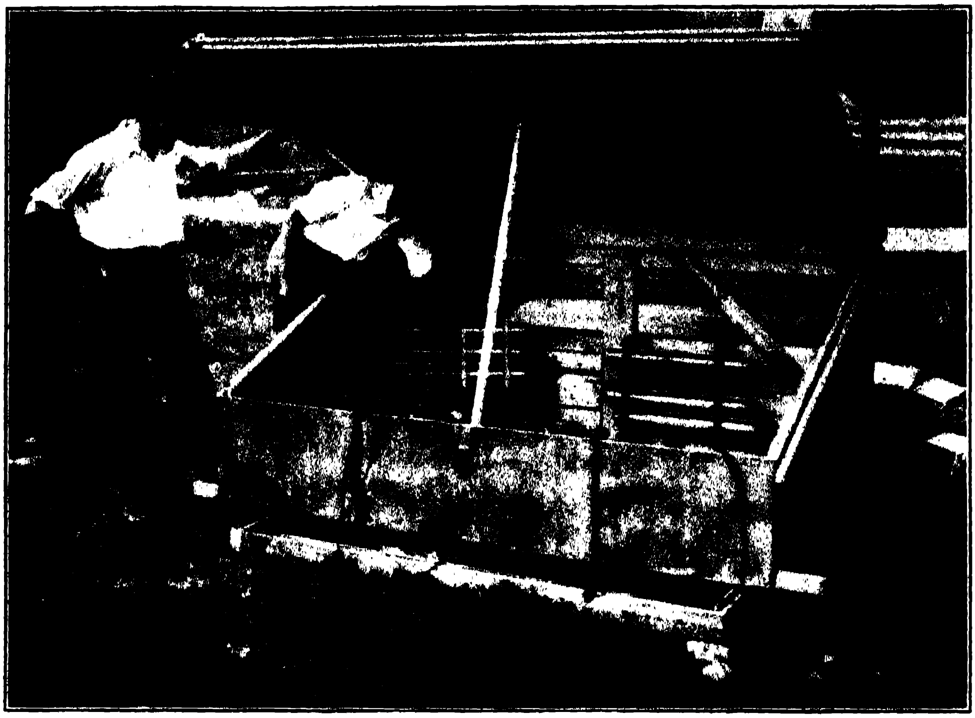
That superior intelligence is an inheritable trait was indicated by experiments reported by Dr. R. C. Tryon, of the University of California. He has propagated two inbred strains of rats, one more intelligent than the average, the other less intelligent. Animals of the superior strain maintain their superiority throughout most of their life span, and are succeeded by superior progeny. In this experiment, environmental factors were kept under control as completely as possible. The inheritance of physical factors such as weight, sex, pigmentation and fertility seemed to have no relation to the inheritance of mental ability.

COSMIC RAYS AT FORTY BILLION VOLTS

A NEW estimate of the energy of cosmic radiation, by Dr. Thomas H. Johnson, of the Bartol Research Foundation of the Franklin Institute, sets its voltage forty times higher than the highest guess previously made, and far beyond the possibility of synthetic duplication by any apparatus at present constructed or even imagined. If this estimate proves to be of the correct order of magnitude, physicists must perforce be contented with studies of the radiations as they naturally occur, for their production under controlled laboratory conditions will be out of the question for a long time to come.

The clue on which Dr. Johnson worked was furnished by photographs made at the California Institute of Technology by Dr. Carl D. Anderson. These indicated that at least some of the radiations commonly measured are secondary, arising from the collision of cosmic rays with particles of earthly origin. Calculations based on this fact indicate an energy content of the primary cosmic rays at the earth's surface of about twenty billion volts. Dr. Johnson estimates their energy at the outer limits of the atmosphere to be about double this, or forty billion volts. This is a figure forty times higher than the present estimates, and four hundred times higher than Millikan's original modest estimate of ten million volts.

The still mysterious source of cosmic rays, conjectured by Millikan to arise in the formation of new elements in outer space, is sought in a new place by one of his colleagues at the California Institute of Technology, Dr. R. M. Langer. Dr. Langer sees them as a possible by-product of the combination of positive and negative magnetic poles, set up by Dirac as the beginning-points of atomic construction with the positive electron,



DIRECTION FINDER FOR COSMIC RADIATION

DR. T. H. JOHNSON AND DR. J. C. STREET, OF THE BARTOL RESEARCH FOUNDATION OF THE FRANKLIN INSTITUTE, WITH APPARATUS USED ON MT. WASHINGTON TO SEEK FOR POSSIBLE DIRECTIONAL EFFECTS IN COSMIC RADIATION.

newly suggested also by Dr. Anderson's photographs. The energy given off by such a combination would be of the same order as that of cosmic radiations.

In the meantime, field observations of these radiations continue with increasing exactness. Dr. Millikan has had recording electroscopes carried in airplanes to altitudes of over 20,000 feet in northern Manitoba and elsewhere. He has also repeated his observations at Arrowhead Lake, in California, using the same recording electroscope instead of the original visual observations.

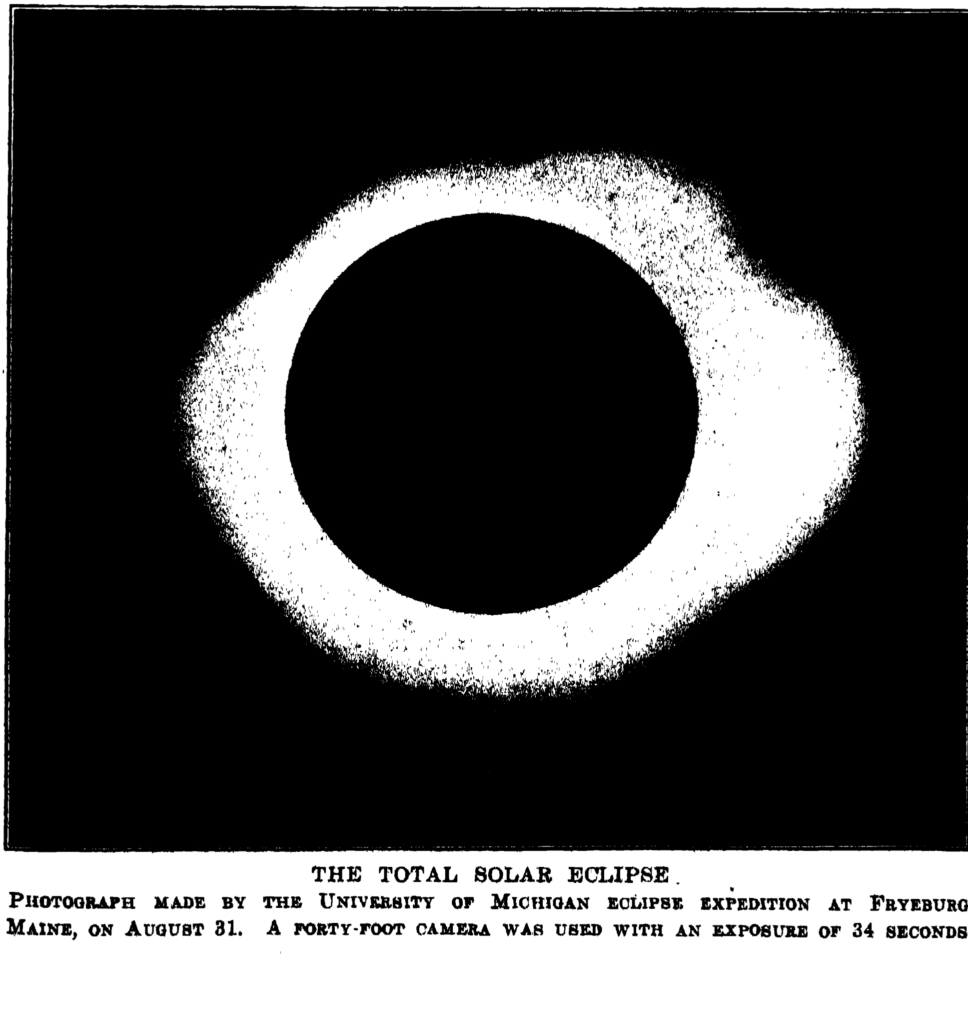
The possibility of a partial north-and-south orientation of the cosmic ray incidence is indicated by results of observations on Mt. Washington, New Hampshire, by Dr. T. H. Johnson and Dr. J. C. Street, of the Bartol Research Foundation. They used a "telescope" in which three Geiger-Muller counters were connected in series, so that the same ray had to pass through all three in order to be counted at all. Their directional results, though not large, are sufficiently within the limits of probable error to indicate that the effect is real. This work lends support to similar conclusions reached by Dr. A. H. Compton, of the University of Chicago, who has been making observations through a wide range of longitude during recent months.

Penetrating radiations resembling the cosmic rays, though of a much lower order of intensity, seem to be released during lightning flashes, Drs. B. F. J. Schonland and J. P. T. Viljoen, of the University of Capetown, state, in a communication to *Nature*. They used a Geiger-Muller counter while distant thunder storms were in progress, and obtained a high rate of coincidence in the instrument's "kicks."

PRELIMINARY RESULTS FROM THE TOTAL ECLIPSE

ALTHOUGH it is of course as yet too early to expect full astronomical results from the many expeditions that set up their cameras and other apparatus in the eclipse path through Canada and New England last August 31, nevertheless there are a few preliminary results worth brief mention. Astrophysical and meteorological observers were on the watch as well as astronomers, and their data first became available.

One of the most keenly watched phenomena during and immediately after the eclipse was the behavior of the Kennelly-Heaviside layer, for it was a moot point between American and British radio engineers whether this ionized reflecting layer in the upper atmosphere is caused by solar radiation or by a bombardment with corpuscles shot out from the sun with a velocity much less than that of light. Observations by physicists of the U. S. Bureau of Standards and by Canadian physicists agreed in supporting the American contention that radiation, presumably ultra-violet, is responsible. The "corpuscular eclipse" failed to materialize. The critical frequency of the E or lower region of the Kennelly-Heaviside layer decreased approximately a thousand kilocycles during the eclipse, lagging



THE TOTAL SOLAR ECLIPSE.

PHOTOGRAPH MADE BY THE UNIVERSITY OF MICHIGAN ECLIPSE EXPEDITION AT FRYEBURG, MAINE, ON AUGUST 31. A FORTY-FOOT CAMERA WAS USED WITH AN EXPOSURE OF 34 SECONDS.

NEW HEAD OF INTERNATIONAL ASTRONOMICAL UNION

DR. FRANK SCHLESINGER, DIRECTOR OF THE YALE OBSERVATORY, WHO WAS CHOSEN PRESIDENT OF THE UNION AT ITS MEETING HELD AT HARVARD UNIVERSITY AFTER THE SOLAR ECLIPSE. THE NEXT SESSION OF THE UNION WILL BE HELD IN PARIS IN 1935.

behind its phases by approximately five minutes. After return to normal no later effects were observed.

Dr. Charles F. Brooks, of the Blue Hill Observatory, Massachusetts, watched for wind and other meteorological effects along the eclipse path, being aided by volunteer observers at many points who sent up pilot balloons, while Dr. Irving Langmuir, of the General Electric Company, ascended to a height of 9,000 feet in an airplane. A definite change in wind direction, from south to east, blowing from the eclipse path, was observed.

Astronomers met with varying fortune. Cloudiness was heaviest inland and least on the Maine coast, so that in general results were poorest in Quebec and best in the Portland neighborhood. The Harvard University and Japanese expeditions had the most nearly perfect conditions, and took full advantage of them. The reports that the Japanese observers had detected a new element in the sun, widely circulated by the press the day after the eclipse, were categorically denied by them. The corona, as observed and photographed by several expeditions, was of the sunspot-minimum type.

Anticipating the unsatisfactory weather conditions, several observers had arranged to get above the clouds in airplanes, and for the first time in eclipse-observing history an autogiro was used for this purpose. On the ground, two parties, one headed by Professor John Q. Stewart, of Princeton University, the other by Dom Maurus Moorat, of Ramsgate Abbey, England, raced the cloud shadows in automobiles, both finally succeeding in finding favorable locations to set up their portable equipment and make visual observations.

EARTHQUAKE AND HURRICANE

THOSE twin angels of destruction, earthquake and hurricane, have been more than ordinarily active during recent weeks. There have been several severe shocks, but fortunately only one of them affected a thickly populated region.

That one, however, made up in its destructiveness for the lack of disaster to follow the others. On Monday, September 26, a quake of most unusual violence shook the Greek coast in the region of the peninsula of Khalkidike, causing considerable loss of life, great destruction of property, and some damage to the historic monastic buildings in

HOMES WRECKED BY THE EARTHQUAKE IN GREECE

DAMAGE WROUGHT BY THE HURRICANE IN PUERTO RICO

the famous Mount Athos region. To the loss of life occasioned by the earthquake itself must be added many drownings, when the small island of Amogiana, to which refugees from the mainland had fled, was flooded—some accounts stating that it had sunk beneath the sea. Strong after-shocks continued to be felt for more than a week following the main disaster. The epicenter of this earthquake was under the sea a little distance off the coast of Khalkidike; this point was determined by the U. S. Coast and Geodetic Survey and the Jesuit Seismological Association, under their cooperative arrangement with *Science Service* as the clearing-house for telegraphic transmission of earthquake data obtained by seismological observatories.

Three days before the Greek disaster, an earthquake centering in southeastern Siberia was located by the same agencies. Since this is a region well off the main lines of communication, direct news of this earthquake may be some time in reaching the outside world. On previous occasions, earthquakes traced to interior Asia by calculation from instrumental data have been reported by courier weeks later.

On October 1 an earthquake of moderate intensity shook the city of Managua, in Nicaragua, the victim of a major earthquake disaster on March 31, 1931. This quake was traced to an epicenter at sea a short distance off the Pacific coast of Nicaragua.

The destructiveness of the Old World earthquake was more than matched by that of a New World hurricane, which raged through the West Indies during the last days of September, wreaking especial havoc in Puerto Rico, which has been staggering slowly to its feet after a similar misfortune four years ago.

The Puerto Rican storm was the fifth of the present season. According to the U. S. Weather Bureau, three such disturbances can be expected in a normal year. One of the previous storms was also unusually severe. It appeared to be headed straight for southern Florida, but when it was only two hundred miles off shore it veered sharply from its course and spent its force over the Atlantic Ocean.

THE PHYSIOLOGY OF RESPIRATION

Professor Otto Warburg, working with Dr. Walter Christian at the Kaiser-Wilhelm Institut für Biologie at Berlin, has discovered a second respiration ferment, distinct from haemin, the earlier discovery of which won for him the Nobel Prize in medicine and physiology in 1931.

Professor Warburg and Dr. Christian found that anaerobic organisms shaken up with oxygen underwent a respiration which could not be stopped by carbon monoxide or hydrocyanic acid, poisons which inhibit the action of haemin. They also found the same action to take place with expressed juices from ordinary aerobic cells. This appeared to indicate the existence of a respiration ferment other than haemin.

They have succeeded in isolating this ferment. It is present in high concentrations in anaerobic cells. It is an orange-colored substance that breaks down when heated for ten minutes at 60 degrees Centigrade.

A hitherto unnoticed respiration phenomenon has been observed at the Westinghouse Research Laboratories at East Pittsburgh, Pennsylvania, by V. Everett Kinsey. He placed pieces of normal and of cancerous human tissues in specially constructed glass respiration chambers, and exposed them to x-rays. Upon analysis of the gases in the chambers after the treatment, he found hydrogen, which is not normally an end-product of respiration. He is of the opinion that the disturbance of metabolism which causes this abnormal loss of free hydrogen is the cause of death of both normal and cancerous tissues subjected to prolonged x-ray exposure.

THE SCIENTIFIC MONTHLY

DECEMBER, 1932

THE AGE AND SIZE OF PLANTS

By Professor CHARLES JOSEPH CHAMBERLAIN

UNIVERSITY OF CHICAGO

WE are all interested in things which are old and things which are big; and the older and bigger, the more we are interested. As one enters the new Oriental Museum at the University of Chicago, he sees rude, chipped flints, some of them so rude that the layman can scarcely decide whether they have been chipped intentionally or have just happened to be that way; then come others, in which even the layman can see intelligent chipping. In the next cases one sees the immense improvement which marks the Neolithic stage of our ancestry. How old are these things? Archeologists guess that it has been about half a million years since the chipping began. We look down the aisle and see the winged bull from Sargon's palace, and then the lions which adorned the entrance to Nebuchadnezzar's royal halls long before he began to eat grass like an ox. We are human and we have a human interest in such things. But one does not need to be a botanist to have an interest in the age and size of plants.

The age of any individual animal or plant is rather short; and animals do not live nearly so long as plants. A turtle has been known to have reached the age of 370 years; but it could hardly be claimed that they were years of strenuous activity. The higher plants are fixed to one spot for their whole lifetime and often reach a ripe old age.

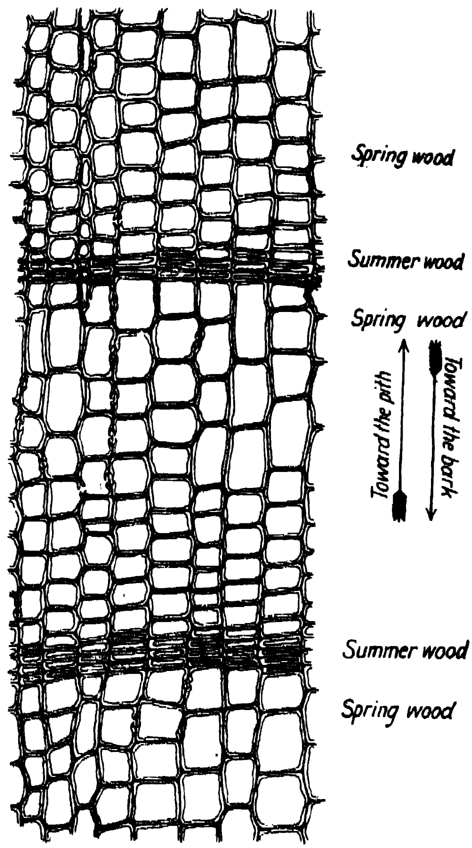


FIG. 1. CROSS-SECTION OF A PIECE OF WOOD OF WHITE PINE

SHOWING ONE COMPLETE ANNUAL RING AND THE SPRING WOOD OF TWO OTHERS. MAGNIFIED 50 DIAMETERS. FROM CHAMBERLAIN'S "ELEMENTS OF PLANT SCIENCE."

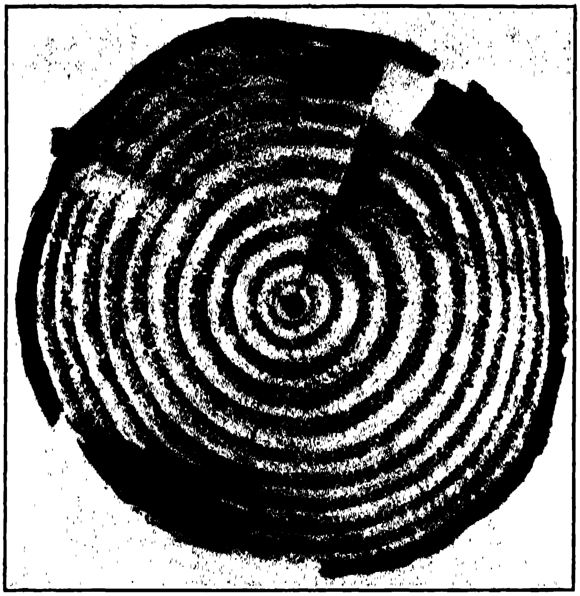


FIG. 2. CROSS-SECTION OF TRUNK OF AN 11-YEAR-OLD DOUGLAS FIR
THE DARKER PART OF THE ANNUAL RING IS THE SPRING WOOD AND THE LIGHTER PART IS THE SUMMER WOOD. ONE HALF NATURAL SIZE. FROM CHAMBERLAIN'S "ELEMENTS OF PLANT SCIENCE."

Some plants, like many of our worst weeds, live only one year; some, like the thistle, live two years; and others, like our shrubs and trees, live longer, hundreds or even thousands of years.

The oldest of all living things are trees, and among the trees whose age is most definitely known are the Gymnosperms of our Pacific region. For obvious reasons, they were not included in the original seven wonders of the world; but if travel had not been so restricted in those provincial days, our big trees might well have stood at the head of the list. The age of a tree is determined by counting its annual rings. A plant consists entirely of cells, which, at first, are more or less cubical; but which later assume various forms. In the wood, which constitutes nearly the whole mass of a tree, they are greatly elongated. The cells formed in the spring are large and have comparatively thin walls, while those formed in the summer are small and have thicker walls (Fig. 1). In our latitude there is scarcely any formation of cells in the autumn, and, of course, none in winter. In a cross-section of a piece of wood, as one views it with the naked eye, the small cells of the summer wood look like a dense line. Since the loose, thin-walled cells of the spring wood alternate with the crowded, thick-walled cells of the summer wood, there is a series of annual rings, denser on the outside and softer inside. Hence, to determine the age of a tree, one has only to count the number of annual rings, a simple matter where extensive lumbering is going on. The counting is done on stumps, since counting at the top of a tree would reveal nothing in regard to the age. A tree hundreds of years old would show only one ring at the top.

In a temperate climate, or even in a subtropical or tropical climate with well-marked rainy and dry seasons, the an-

nual rings are distinct and easily counted; but in some of the warmer climates, where the rainy and dry seasons do not alternate so sharply, the zone of wood formed during any year is not so conspicuous. It can be distinguished, but there may be several intermediate rings. While these would not confuse a botanist, they would enable a clever lawyer to confuse a jury in regard to the length of time some piece of land, upon which the trees might be growing, had been in the possession of his client. A comparison of a section of a young Douglas fir (*Pseudotsuga taxifolia*) trunk, growing at Puget Sound Biological Station, with a section of the Australian pine (*Casuarina equisetifolia*), growing on Dry Tortugas, Florida, shows what a difference there can be in annual rings (Figs. 2 and 3). Any one can count the rings in the Douglas fir; but those of the Australian pine are somewhat confusing. Even in a temperate climate, two rings are sometimes formed in one year. When a peach tree flowers in the autumn, the same stimulus which caused the untimely flowering causes a resumption of growth in the wood; but the second ring is weak and does not confuse the botanist in determining the age of the tree.

Thorough work in determining the age and size of trees has been done in our Pacific region. Sudworth's "Trees of the Pacific Slope," published in 1908, presents interesting information along this line; but, since that time, the study

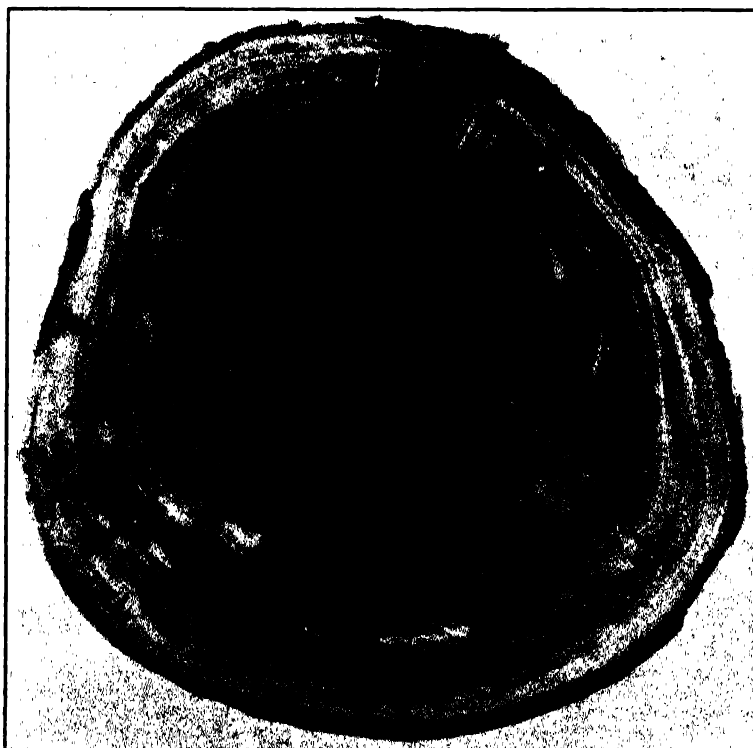


FIG. 3. CROSS-SECTION OF A BRANCH OF AUSTRALIAN PINE (*CASUARINA EQUISETIFOLIA*)

GROWING AT DRY TORTUGAS, FLORIDA. THE BRANCH IS 7 YEARS OLD AND 4½ INCHES IN DIAMETER.

of annual rings has progressed beyond the mere counting of their number. In a favorable year, the ring is broader than in an unfavorable year. The seven years of plenty followed by seven years of famine may be recorded in the rings of old trees; and a century of aridity, which may have caused migrations of people, may have left its date in old trees.

In any discussion of the age and size of plants, the trees of our Pacific region should have a prominent place, both on account of their great age and size and on account of the scientific accuracy of the determinations.

Our Western pines are magnificent trees. The Western yellow pine (*Pinus ponderosa*) is often 150 feet high and 350 years old, with occasional specimens 200 feet high, 8 feet in diameter and 500 years old. The sugar pine (*Pinus lambertiana*) is still larger, often 180 feet tall and 7 feet in diameter; and one large tree, near the Calaveras Grove in California, is 11 feet in diameter and more than 200 feet tall. It is probably 600 years old and is the largest known pine in the world.

The Western larch (*Larix occidentalis*) is frequently 180 feet high, 4 feet in diameter and 560 years old, with exceptionally large specimens 700 years old. The Alpine larch (*Larix lyallii*) is comparatively small, only 30 or 40 feet high and 1 or 2 feet in diameter; but 600 years is not an unusual age and some specimens are known to be 700 years old.

The Engelmann spruce (*Picea engelmanni*) is a beautiful, symmetrical tree, often 100 feet tall and 3 feet in diameter; but the rings are very narrow, so that trees less than 2 feet in diameter may show as many as 200 rings.

The Douglas fir is the most important lumber tree of the West. It is often more than 180 feet high and 6 feet in diameter, with occasional trees 200 feet high and 10 feet in diameter. A tree 4 feet in diameter will be about 200 years old; 8 feet in diameter, 400 years old. The Long-Bell Lumber Company is planting millions of trees and expects them to reach, in 35 years, a diameter of 18 inches, the best size from the standpoint of the lumberman.

Forest fires too often prevent trees from reaching the anticipated age. In our Eastern and Middle Western forest regions we can only partly appreciate the havoc wrought by a fire when it gets started in a forest of Douglas fir. Most

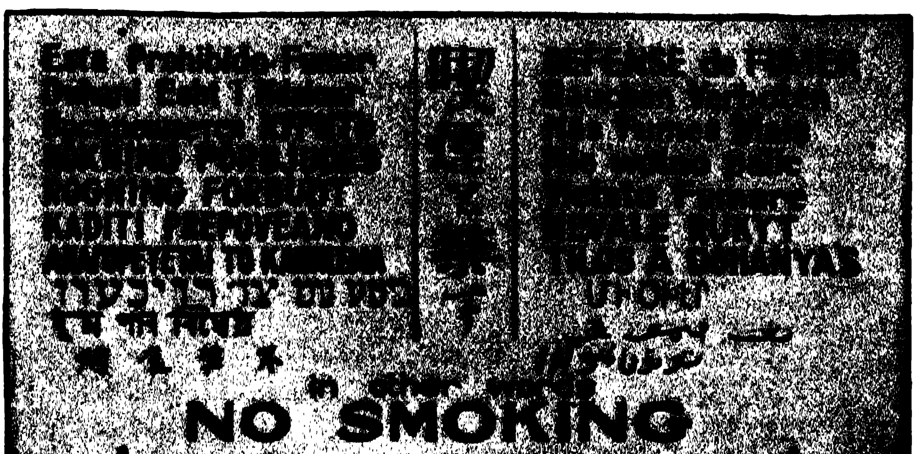


FIG. 4. SIGN AT ENTRANCE TO THE LONG-BELL LUMBER COMPANY'S PLANT

FIG. 5. THE BIG TREE OF TULE
FROM CHAMBERLAIN'S "ELEMENTS OF PLANT SCIENCE."

FIG. 6. *SEQUOIA GIGANTEA*
IN THE MARIPOSA GROVE, CALIFORNIA, BURNED COMPLETELY THROUGH. THE MAN, MAJOR LOEHWING, IS MORE THAN 6 FEET TALL.

fires can be charged to tobacco; so the sign at the entrance of the mill of the Long-Bell Lumber Company is not a joke (Fig. 4).

The most famous of all big trees are the Sequoias of California, named after a remarkable Indian chief who invented a phonetic alphabet and taught the braves of his tribe to read and write. There are two species, the redwood (*Sequoia sempervirens*) near the coast, throughout the northern half of the state, with a few trees in Oregon and some as far south as Monterey; and the Big Tree (*Sequoia gigantea*) farther inland, near the central eastern part of the state on the western side of the Sierras. The redwood often grows in dense stands with average large trees 300 feet high, 15 feet in diameter and 1,000 years old. The largest specimens are 350 feet high, 20 feet in diameter and 1,300 years old.

The other species does not grow in dense stands, but in scattered groups, connected by straggling specimens. It is not as tall as the redwood, but is more majestic and is entitled to its name, the Big Tree. The larger trees are from 250 to 280 feet high, with occasional individuals 300 to 330 feet high. In the Calaveras Grove, a house has been built on the top of a stump, the floor, 27 feet in diameter, being the planed-off top of the stump.

Many of the larger trees have their own names, the Illinois Tree, Wisconsin Tree, Vermont Tree, etc., and trees are named after prominent people, the General Grant Tree, the General Sherman Tree; and it is fitting that some of them should be named after botanists, so we have the Asa Gray Tree and the John Torrey Tree.

Recently an attempt was made to find out which might be the biggest of the Big Trees. From the standpoint of the lumberman, the General Sherman is the largest, for it would make 50,000 feet of lumber; the General Grant would make 45,000 feet, and the Hart Tree, 34,000 feet. But the Hart Tree is the tallest, 277 feet high; the General Sherman five feet shorter, and the General Grant ten feet shorter. The General Grant tree has the largest diameter, 33 feet; while the diameter of the General Sherman is 30 feet, and that of the Hart Tree only 26 feet. Which is the biggest? It is like deciding a beauty contest. One girl has the most beautiful hair, another the most beautiful teeth, while another has the most beautiful figure. Which one gets the apple? And which tree gets the medal?

Perhaps none of them. For we have overlooked the Big Tree of Tule, about 250 miles south of the old City of Mexico (Fig. 5). This tree is 50 feet in diameter, not measured at a flaring base, for it is fifty feet in diameter where it begins to branch. It is a Montezuma cypress (*Taxodium mucronatum*), a giant among its kind, like Goliath or the nine and one half foot man of the side show.

How old is the Big Tree of Tule? The most conservative estimate, based upon counting the rings of part of a tree about 4 feet in diameter, would not make the age less than 5,000 years, and it may be much older. Professor W. J. G. Land, who paid particular attention to the wound tissue around the Humboldt inscription and who is a profound student of plant anatomy, thinks that 7,000 years would not be too great an estimate. While the pyramids of Egypt were being built, and later, while Achilles was dragging the dead body of Hector around the walls of Troy, and while Moses was leading the children of Israel out of the wilderness, it was a big tree; when Romulus was killing Remus it had already passed the usual size of its species; when Socrates was drinking the hemlock, it must have been in the legendary stage; and in the days of King

FIG. 7. *DIOON EDULE*

A CYCAD, AT CHAVARRILLO, MEXICO. FIVE FEET TALL AND ABOUT 1,000 YEARS OLD.

FIG. 8. MONTEREY CYPRESS (*CUPRESSUS MACROCARPA*)

Arthur and his table round, pious pilgrims had begun to come and worship this awe-inspiring wonder of nature, as they still come to-day. Even a blasé university professor can not suppress a feeling of awe and veneration as he gazes upon the oldest living thing in the world, a tree which has seen mankind emerge from savagery and climb to its present exalted, semi-savage condition.

The Mexican government should be commended because it will not let John Doe of Kankakee or Sam Jones of Sing Sing carve their names on the bark of the Big Tree of Tule. More than a hundred years ago, before the Mexicans realized that a sacred tree needed any protection, the traveler, Alexander Humboldt, cut through the bark to the wood and carved an inscription, the beginning and end of the lines of which are now overgrown by wound tissue. If he had made accurate measurements and recorded them, instead of merely showing that the great Humboldt had been there, such data might have been a partial excuse for his vandalism.

We should all be grateful to the "Save the Redwoods" league, and to other lovers of nature, for checking the ravages of greedy capitalists who can see only so many feet of lumber and so many dollars in these magnificent trees, which could not be replaced in a thousand years. Many of the Big Trees have tunnels at the base, so that you can drive through and have your picture taken; but these tunnels are not the work of reckless vandals. Accidental fires have burned the holes through and they were merely trimmed into more symmetrical passages (Fig. 6). People have been driving through the "Wawona" tree for more than fifty years, and it seems to do no damage. Some of these burned tunnels are more than fifty feet high, but the trees still stand against the wind and the weather. Fortunately, there are

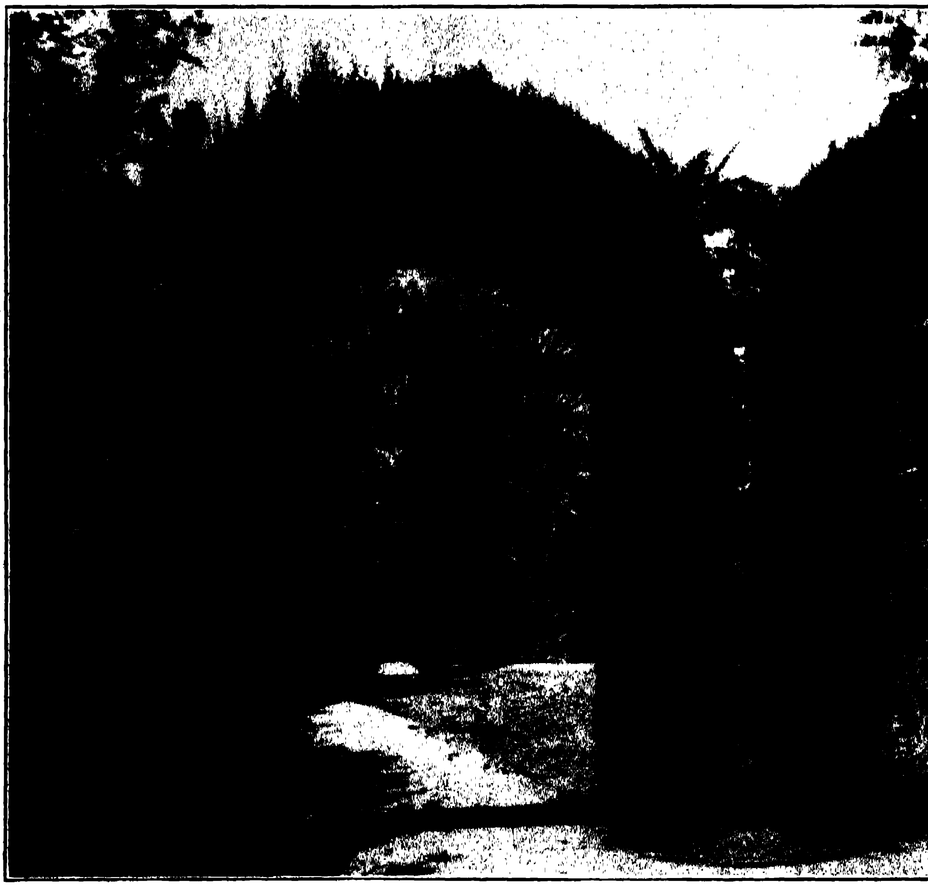


FIG. 9. AN ARCH OF MONTEREY CYPRESS AT LOS ANGELES, CALIFORNIA

now many parks and reservations where fire and wind are the only enemies with which these splendid trees have to contend.

So far we have considered trees in which great age and great size are associated. No less interesting are plants which reach a great age without a corresponding increase in size. The cycads constitute a small, tropical and subtropical group of seed plants, related to the ferns. Most of them have tuberous, subterranean stems, but many of them have trunks surmounted by a crown of leaves, which makes them look like tree ferns or palms (Fig. 7). As the leaves die, the leaf bases remain on the plant and can be counted. Knowing the average number of leaves in a crown, and also how often a new crown is produced, one can count the number of leaf bases and estimate the age of the plant. If there are 20 leaves in a crown and a new crown is formed every other year, the average is ten leaves a year. If there are 10,000 leaf bases, the age is 1,000 years. The plant shown in Fig. 7 is scarcely more than 5 feet in height, but it has reached the honorable age of 1,000 years; but even a thousand years does not mean that it is dying of old age. When a cycad reaches a height of 4 or 5 feet, the big crown of leaves offers great resistance to wind, and some furious tropical

storm either blows the plant down or makes it lean. The leaning habit is almost universal in the taller cycads. The wood is so heavy that any increase in size accentuates the leaning, and finally the plant falls. But young shoots come up from the ruptured base, so that it is common to find cycads in groups. What age a cycad might reach under ideal conditions is problematical.

With many of the cycads such a slow growth is natural; but many trees grow very slowly when exposed to severe conditions. A western yew, 6 inches in diameter, may be nearly a hundred years old. The Monterey cypress, which is now cultivated the world over in warmer climates, becomes a large, symmetrical tree, but in its native habitat along the wind-swept Monterey Bay it becomes gnarled and twisted, with a flattened top, and trees a foot in diameter may be 50 or 60 years old (Fig. 8). This cypress withstands not only extreme exposure to weather, but can be pruned and trained to an almost unbelievable extent. In California it is popular for hedges, and one often sees an arch made by bending and fastening two young trees together (Fig. 9). By constant pruning and care—or lack of it—these hedges and arches remain small for many years.

The Japanese keep the pines, especially *Pinus thunbergia,* in vases almost indefinitely, preventing any considerable increase in size by taking them out of the vase occasionally and shaking off the soil and repotting. Such trees are handed down from father to son, generation after generation. Some of them, still thriving, are known to be 200 years old.

Practically nothing is known about great age in any of the microscopic plants, but it has been claimed that asexual unicellular organisms are immortal; because reproduction is merely cell division. A cell divides and there are two individuals; each of these divides, and there are four; and so on. Thus, a part of the original cell is still alive, even after millions of years. The claim needs no argument: the truth of it is self-evident. But why should the claim be confined to unicellular organisms? The phenomenon is universal in plants from the lowly unicellular forms up to the highest. There is no death of the entire organism. You have all heard, "Unless the grain of wheat fall into the ground and die, it remains alone; but if it die, it beareth much fruit." Of course, the embryo in the grain of wheat does not die. It was an integral part of its parent, and a part of it will become another embryo; and so there is a continuity of living matter. The same is true of animals, whether they be unicellular organisms or at the human level. So, if there was one original human being, a living part of that original being is a living part of every living being on the earth to-day. The individual dies, but there is continuity of living matter until a race becomes extinct.

In a popular sense, however, we may think of our Western Sequoias and the Big Tree of Tule as the oldest living individuals in the world.

HOW CHANGES ON THE SUN'S SURFACE ARE RECORDED BY THE EARTH'S MAGNETISM

By J. BARTELS

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THE Sun always appears the same to us, while the Moon's aspect changes from day to day. It has long been known, however, that this difference is merely pictorial. As a matter of fact, the Moon always turns towards us the same rocky face, more or less illuminated by the Sun's rays. The Sun, on the other hand, is a glowing ball of gas, with an ever-changing surface on which dark spots can often be seen, sometimes large enough to be visible to the eye through a piece of smoked glass. All spots appear to move across the Sun's disc from east to west. Many single spots and groups of spots which have passed from sight around the Sun's western limb have been recognized on their reappearance, after about two weeks' time, at the eastern limb. It has been concluded from the recurrences of such groups that the period of the Sun's rotation is about 27 days. To be more precise, the interval elapsing between two successive passages of a spot across the Sun's central line is a little less than 27 days for spots on the Sun's equator, and this interval increases to more than 28 days for those midway between the equator and the poles. Spots are rarely observed any nearer to the Sun's poles. The outlines of sunspots are not the same; some do not reappear at all, and others exist through several rotations, but very seldom indeed do they persist for longer than half a year.

Since the conditions on the Earth depend so much on the Sun, any effects of sunspots on terrestrial phenomena have been eagerly sought. These investigations have led to the idea that the Sun ejects, from well-defined areas on its surface, clouds or streams of particles—electrons, ions and molecules. These streams finally enter the Earth's atmosphere, but do not penetrate far downward, because they are stopped by the atmosphere before they approach within 50 miles above the Earth's surface. (This is, by the way, not the only case in which the atmosphere protects us from outside influences; meteors, for example, are dissipated in the air and thus seldom reach the Earth's surface, and the powerful ultra-violet radiation of the Sun is intercepted by a small quantity of ozone in the upper atmosphere.)

The assumption of the solar streams is based on indirect information, depending mainly on two phenomena. One is the glow excited in rarefied air by the impact of the solar particles—observed by us as aurora. The other is the system of electric currents set up by the solar particles in the highest regions of the atmosphere, the effects of which we observe in irregular changes, or disturbances, of the Earth's magnetic force. We shall deal here only with the latter, since they are continuously recorded at more than forty observatories distributed over the entire globe, while aurora is almost exclusively seen in the polar regions, and even there only at night.

In order to trace the solar influence on the Earth's magnetism, we may consider the varying degree of magnetic

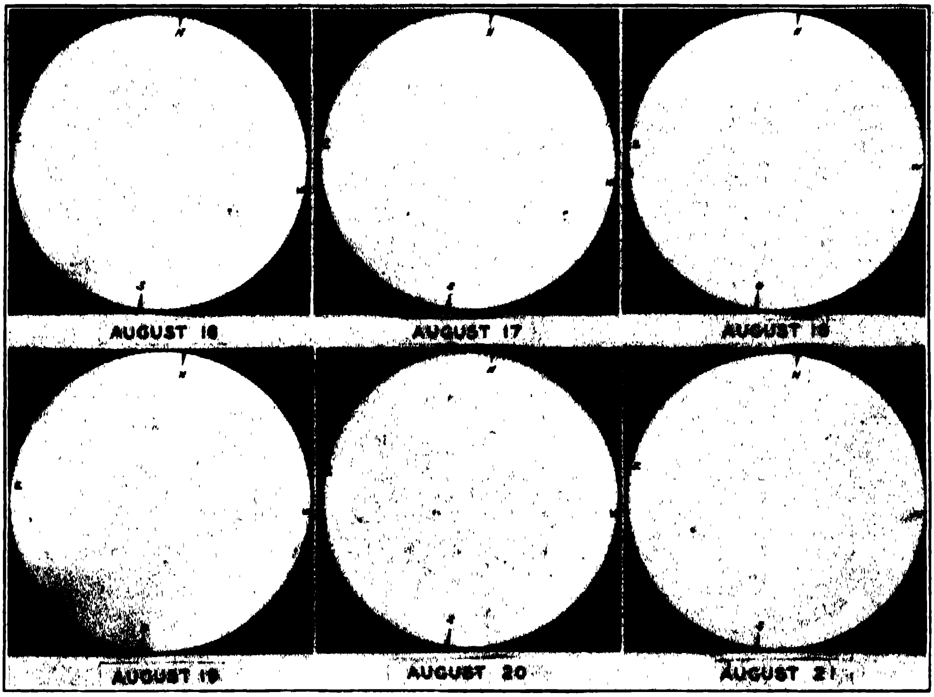

FIG. 1. SUNSPOTS MOVING ACROSS SUN'S DISC
PHOTOGRAPHS OF THE SUN TAKEN AT MOUNT WILSON OBSERVATORY ON SIX CONSECUTIVE DAYS, FROM AUGUST 16 TO 21, 1927.

disturbance. During magnetically quiet periods, only regular changes are observed, which repeat themselves day after day. Violent disturbances are called magnetic storms (though no relation to weather and especially to thunder-storms has been found); at times they break out simultaneously all over the Earth and may last for about two days. Such storms occur only from two to five times per year and are always accompanied by pronounced auroras and by currents disturbing cable transmission. Some of these have been definitely connected with the passage of large sunspots near the center of the Sun's disc, or with sudden solar flares. The intermediate stage of moderate disturbance is, however, a quite common phenomenon, about as frequent as polar aurora, which was observed on the Shetland Islands, in the winters 1924–28, on nearly half of all nights on which moonlight or heavy clouds did not prevent observation.

It is important to have a measure for the magnetic activity, that is, the intensity and frequency of magnetic disturbances during a given interval. This is most conveniently obtained by the method of characterization. Each observatory assigns, on the basis of the character of its magnetic records, to each interval of 24 hours between successive Greenwich midnights, a character-number, namely, "0" for quiet, "1" for moderately disturbed, and "2" for greatly disturbed days. The average number for all collaborating observatories is called the international magnetic character-number. This is represented daily in the accompanying Fig. 2 by suitably graded symbols (gray for quiet, black for disturbed days). This

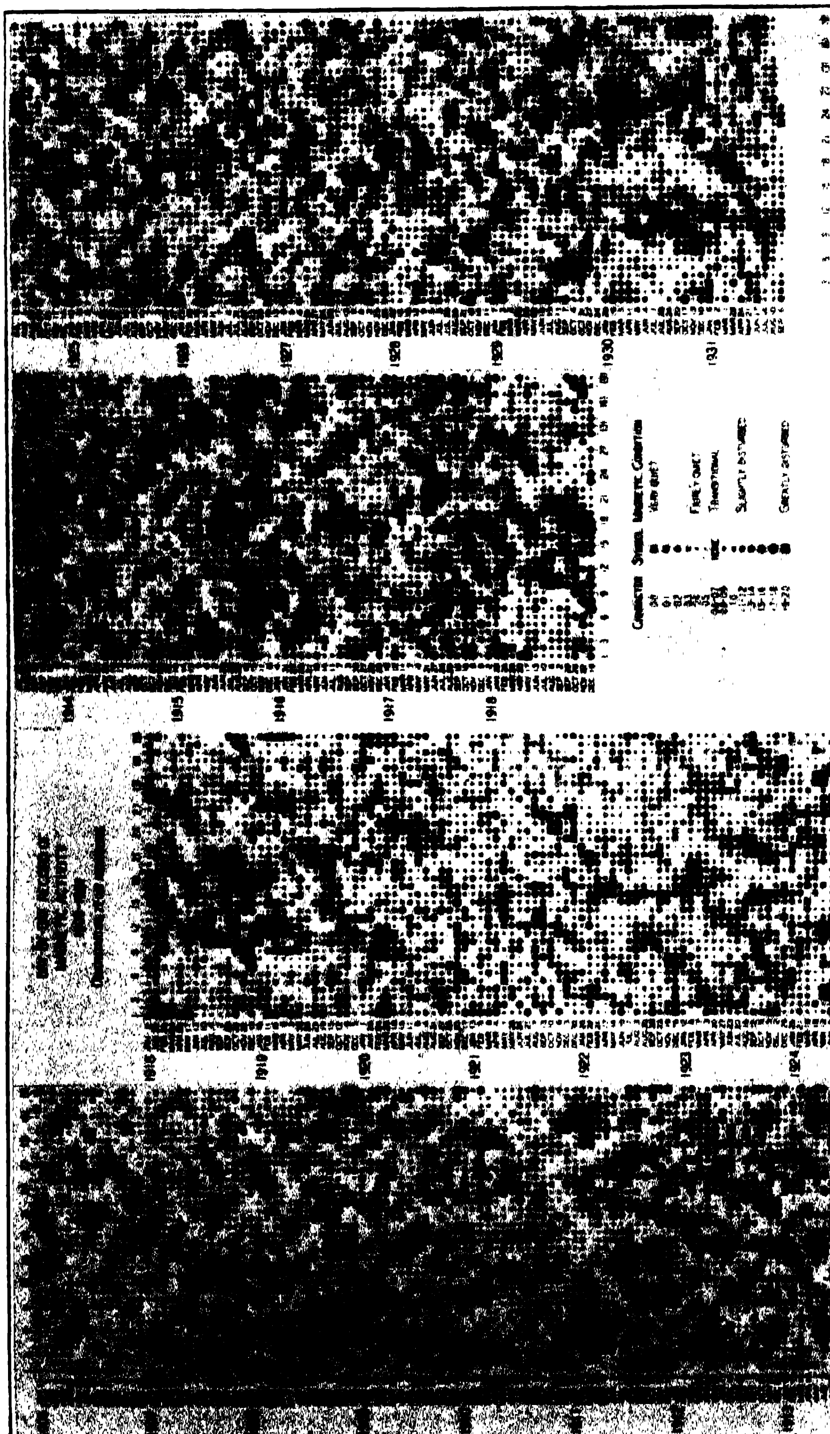

FIG. 2. DAY-BY-DAY RECORD OF MAGNETIC ACTIVITY, 1906–31, SHOWING INTERNATIONAL MAGNETIC CHARACTER-FIGURES BY SYMBOLS ARRANGED IN ROWS BEGINNING WITH DATES SHOWN AT LEFT OF EACH ROW, EACH DATE BEING 27 DAYS LATER THAN THE DATE ABOVE IT, AND DEMONSTRATING 27-DAY RECURRENCE DUE TO SUN'S ROTATION.

figure constitutes a complete record of magnetic activity since 1906, the year in which the scheme of characterization was put into effect.

The record, which contains nearly ten thousand symbols, reads like a book. The date of the first day in each row is indicated on the left, each successive row beginning 27 days later; at the end of each row the first nine days of the next row have been repeated in order to emphasize the continuity of the series. To facilitate reference, the days in each row are numbered 1 to 27. As it happens, considering the transitional condition as being magnetic character-number 0.6 to 0.7 and for which days the space is left blank, the remaining symbols total about as many black as gray on the chart. The years 1906–31 have been arranged in two vertical rows, so that intervals which are eleven years apart appear side by side.

The repetition of quiet and disturbed days after a rotation of the Sun, the 27-day recurrence-phenomenon, is clearly indicated in the record by the distinct vertical columns (sequences) in which the gray and black symbols arrange themselves. Some of these sequences last for a year or even longer. If the recurrence-interval were shorter or longer than 27 days, this would appear in a definite slant of the columns. Thus, a 28-day interval seems to be indicated in the minor disturbances during the second half of 1913 (after day 13), but otherwise 27-day intervals are predominant.

The so-called 11-year sunspot-cycle is also noticeable in the diagram, by the prevalence of gray symbols (quiet days) in the years with few sunspots (about 1911 and 1923), and of black symbols (disturbed days) in the years with many sunspots (about 1906, 1917 and 1928). However, there is no row in the diagram which contains only gray or only black symbols. On the contrary, pronounced sequences of quiet days per-

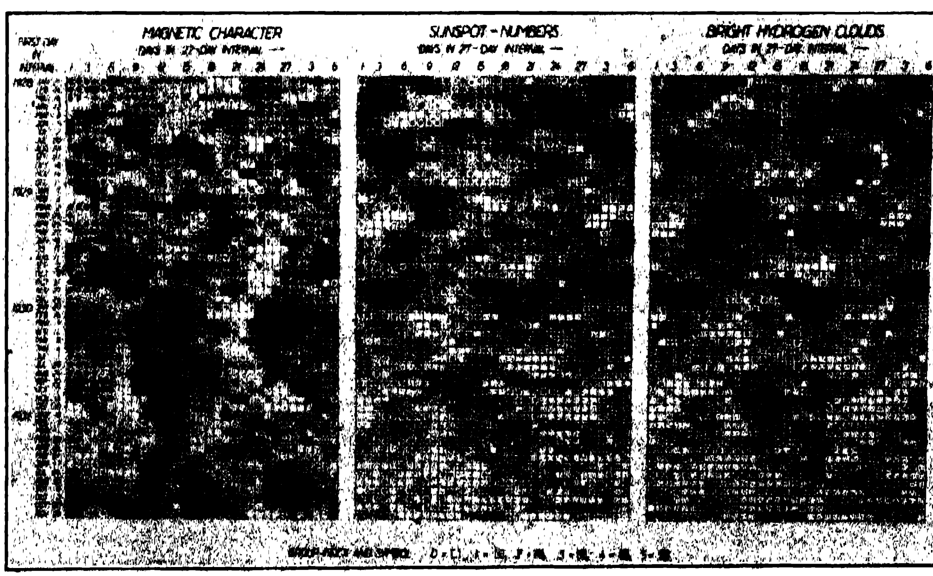

Fig. 3. Day-by-day record, 1928–31, of international magnetic character-figures, relative sunspot-numbers for central zone, and solar indices for bright hydrogen clouds in central zone, each expressed by one of six symbols arranged to show 27-day recurrence-phenomenon—the crosses mark those days for which there were no solar observations.

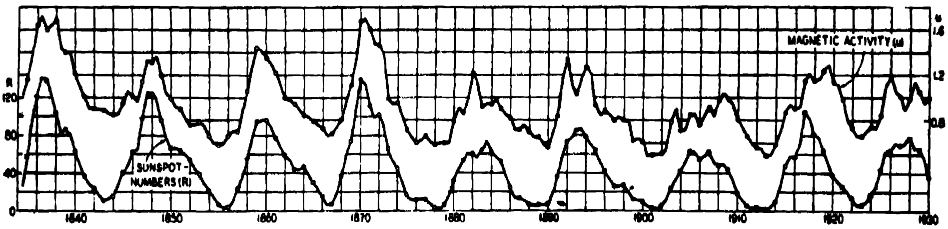

FIG. 4. ANNUAL MEANS OF MAGNETIC ACTIVITY AND RELATIVE SUNSPOT-NUMBERS, 1835–1930. (THE POINTS MARKED BY SMALL CIRCLES ARE THE USUAL YEARLY MEANS FOR JANUARY TO DECEMBER.)

sist near a sunspot-maximum (for instance, in 1917, 1918 and since 1926), and sequences of disturbed days persist near a sunspot-minimum (1911 and 1923). Accordingly, the Sun's surface can never be everywhere quiet or everywhere agitated.

Two or more sequences often run simultaneously, but they never divide the 27-day interval into regular subdivisions. This contradicts the assumption, sometimes made, that the Sun's surface shows a systematic pattern.

Besides the general relationship between sunspots and magnetic activity in the 11-year cycle, exact correspondence is sometimes found even in individual cases. For instance, the greatest storm on the record, that of May 13–16, 1921, was accompanied by the passage of an extremely large, but short-lived, group of spots across the center of the Sun's disc on May 14.

If, however, we attempt to coordinate the individual quiet or disturbed magnetic sequences to similar recurrent spotless or spotted regions on the Sun, we meet, on the whole, with a striking disappointment. In the first place, the magnetic sequences are mostly longer than the life of spot-groups, which are rarely observed to return more than four or five times. Moreover, several magnetically disturbed sequences persisted through times when, for several weeks in succession, not a single sunspot was visible, as, for example, the fine sequence in the first half of 1923 (day 18), with its well-defined occurrences after 27 days.

As a test of this, the diagram (Fig. 3) was prepared in the same manner as

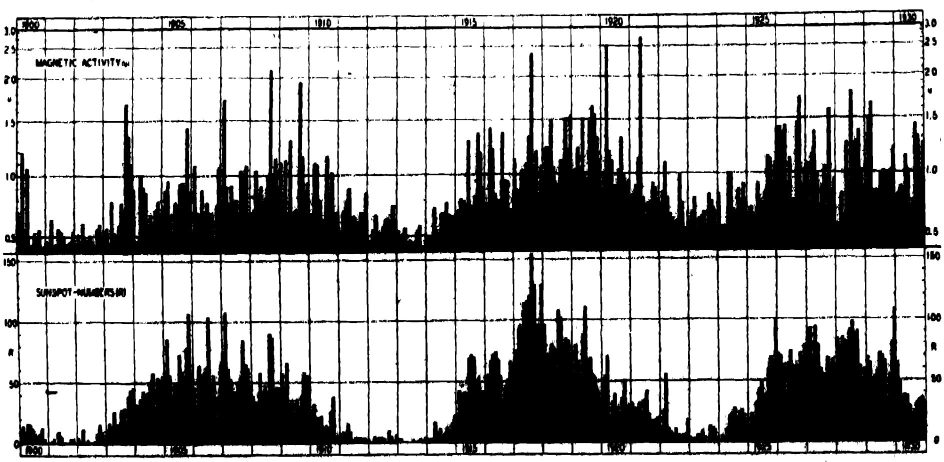

FIG. 5. MONTHLY MEANS OF MAGNETIC ACTIVITY ANN OF SUNSPOT-NUMBERS, 1900–30.

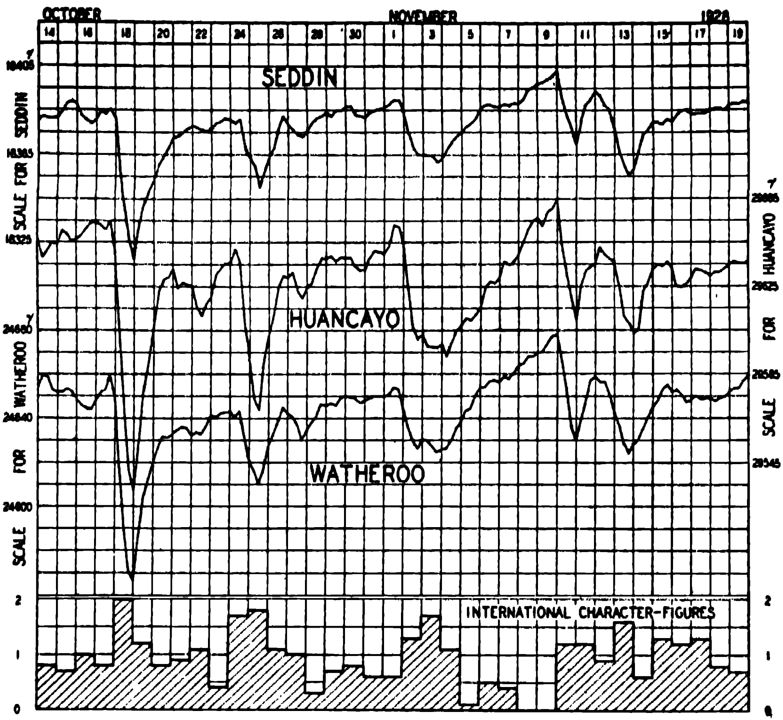

FIG. 6. THE WORLD-WIDE NATURE OF POST-PERTURBATION INDICATED BY SIMILARITY OF THREE CURVES SHOWING THE DAILY MEANS MAGNETIC NORTH COMPONENT AT SEDDIN (GERMANY) AND HORIZONTAL INTENSITY AT HUANCAYO (PERU) AND AT WATHEROO (WESTERN AUSTRALIA), OCTOBER 14 TO NOVEMBER 19, 1928. (PLOTTED MEANS FOR CONSECUTIVE 24-HOUR PERIODS, 6 HOURS APART; THOSE FOR 24 HOURS CENTERED AT GREENWICH MIDNIGHT COINCIDE WITH VERTICAL LINES.)

Fig. 2. The left-hand diagram is a repetition on a larger scale, of the corresponding part, for the three years 1928–30, of Fig. 2 for the international magnetic character-numbers. The other two represent solar phenomena, as obtained by direct astrophysical observations of a central disc of half the Sun's diameter (this being the part of the Sun which is most likely to exert an influence on the Earth), namely, relative number of sunspots and the intensity of bright markings as seen in the light of the hydrogen-line by means of Dr. Hale's ingenious spectrohelioscopes. Again, gray symbols denote quiet conditions, and black symbols denote high activity.

Comparison of the three diagrams shows that sequences in one of the solar phenomena can easily be recognized in the other; sunspots and bright hydrogen-clouds occur, therefore, in about the same regions of the Sun. The pronounced magnetic sequences can not, however, be recognized in either of the solar phenomena—even if the possibility of a lag betweeen a solar outburst and its action on the Earth is taken into account. This is confirmed also for other solar phenomena and leads to the following conclusion:

Terrestrial-magnetic activity reveals persistent solar influences which are distinctly recognized as such by the 27-day recurrence due to the Sun's rotation. Magnetic activity must, therefore, be attributed to some action of fairly defi-

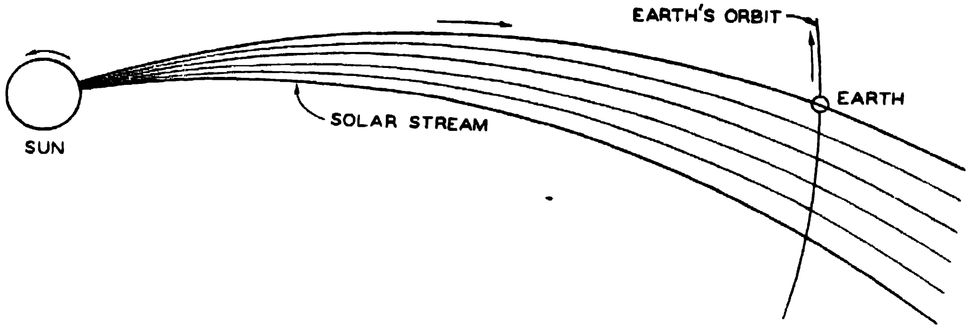

FIG. 7. SCHEMATIC VIEW OF A STREAM OF PARTICLES EJECTED FROM THE SUN (AFTER S. CHAPMAN).

nite regions on the Sun's surface—we call them M-regions. These M-regions can not, at present, be individually identified with any of the phenomena which are directly observed on the Sun. In the averages taken over a number of years, however, the M-regions must vary in area like the sunspots, since magnetic activity shows the 11-year cycle quite distinctly.

This 11-year cycle is shown both in magnetic activity and relative sunspot numbers since 1835 in annual means (Fig. 4) and in monthly means (Fig. 5). Another more objective measure of magnetic activity is represented in these figures; it is based on the fact that the horizontal portion of the Earth's magnetic force varies from day to day very similarly all over the globe, rapidly decreasing during a magnetic storm, and slowly recovering afterward (Fig. 6). The u-measure of activity is (roughly defined) the average change from day to day, regardless of sign, of the magnetic force near the Earth's equator.

The fair parallelism of magnetic activity and sunspots, as shown in Figs. 3 and 4, appears to be absent in certain intervals, for instance, in the three years 1918–20 and 1928–30. The failure of other solar phenomena to show, in the latter interval, better relations to magnetism than sunspots, is the basis of the conclusions drawn above. On the other hand, the good agreement between sunspots and terrestrial magnetism in the other parts of the long series 1836 to 1930 is striking evidence that solar and terrestrial relationships are not steady and can not be fully obtained from the study of short series of observations.

If the solar particles travel in about one and a half days to the Earth, they would form a stream like that shown in Fig. 7, since the source of emission rotates with the Sun. This stream is perhaps not continuous, but may be only a succession of separate clouds. Though each single particle is emitted nearly radially, direct from the Sun's surface, the whole stream seems to rotate around the Sun just like water from a garden hose, and would sweep across the Earth once in about every 27 days, as long as the active region on the Sun persisted. Between the first impact and the time at which the Earth is completely enveloped by the storm, less than one minute elapses, which explains the practically simultaneous beginning of many magnetic storms. The detailed movements of the particles are very complicated, especially near the Earth, where they are deflected by the Earth's magnetic forces. S. Chapman and C. Störmer have attacked this difficult problem from different view-points.

Whatever detailed theory of magnetic disturbances may be evolved, it is clear that magnetism provides us with information regarding fairly persistent solar phenomena, restricted to varying, but always well-defined, regions on the Sun's surface. These are not only of interest for the study of the Sun, because direct astrophysical observations do not reveal them as yet, but are of even greater interest from the terrestrial standpoint, because magnetism records these solar influences only in so far as they actually affect our globe. This information will be useful in the study of radio-transmission, because radio-waves are transmitted around the Earth in the same upper layers of the atmosphere in which the magnetic variations are produced. Beyond faint indications of an 11-year cycle, no such positive proof, however, as yet exists that weather—in other words, the lower atmosphere—is influenced by solar changes in the same straightforward manner as these outermost regions, which are, of course, most sensitive to cosmic influences.

A more extended account of the above will be found in the article by J. Bartels in volume 37, pages 1 to 52, of the March, 1932, issue of the *Journal of Terrestrial Magnetism and Atmospheric Electricity*. Other references bearing on the subject-matter above are: S. Chapman and V. C. A. Ferrero, *Journal of Terrestrial Magnetism and Atmospheric Electricity*, vol. 36, 77–97, 171–186 (1931); vol. 37, 147–156 (1932), and C. Störmer, *Journal of Terrestrial Magnetism and Atmospheric Electricity*, vol. 35, 193–208 (1930).

THE PROPOSED REVISION OF THE GREGORIAN CALENDAR[1]

By HENRY W. BEARCE
U. S. BUREAU OF STANDARDS

WITHIN the past few years much has been written on the subject of calendar revision, and many plans have been proposed for revising and simplifying the Gregorian calendar, by means of which most of the civilized world, including the United States, reckons the passage of time and records the order of events.

The matter has been considered by a special committee of the League of Nations, national committees have been organized in the United States and several other countries, and bills[2] have been introduced in Congress, all looking toward a revision of our calendar.

At the October, 1931, meeting of the Committee on Communications and Transit of the League of Nations, at which 44 nations were represented, it was concluded that disturbed conditions rendered the time inopportune for a general simplification of the calendar. Hope was expressed that general action might be taken before the year 1939, that being the first year after 1933 in which the year will begin on Sunday.

In spite of the publicity that has been given to the question of calendar revision, it may still be said that vital interest in the matter is confined to a relatively small group. The vast majority of persons, while not opposed to calendar revision, are indifferent to it. The defects of our present calendar, when brought to their attention, are readily admitted, but familiarity, through a lifetime of use, tends to minimize the importance of these defects. Probably most of us would prefer to continue to use our present calendar, imperfect though it is, rather than go to the necessary trouble of learning a new one.

If intelligent and well-considered action on the calendar is to be taken before 1939, or at any subsequent time, it is important that a considerable percentage of the people of all nations concerned become somewhat familiar with the more important of the many considerations involved in calendar revision. The day has passed in which calendar revision is likely to be brought about as a result of the efforts or interest of a single individual or even of a small group. The interest must be widespread and the efforts well directed in order to overcome the natural inertia of the public mind and of legislative bodies.

The origin and history of our present (Gregorian) calendar and that of earlier calendars have been so extensively and so ably discussed by others that further treatment of that phase of the subject seems unnecessary. It is perhaps sufficient to say that the Gregorian calendar now in use in the United States and a large part of the rest of the world was adopted in Catholic countries in 1582; in Great Britain and her colonies, including the United States, in 1752[3]; in

[1] Publication approved by the Director of the Bureau of Standards of the U. S. Department of Commerce.

[2] H. R. 12221, May 29, 1922; S. 2862, Jan. 27, 1928; H. J. Res. 334, Dec. 5, 1928.

[3] In Great Britain and her Colonies the calendar year 1751 ended with December 31, and the year 1752 began on January 1. Prior to that time the British civil year had begun with March 25 (except that in Scotland the civil year, from 1700 to 1751, began on March 1). The year 1751 was, therefore, a short year. Having begun March 25 and ended De-

Russia in 1917; and in certain European countries adhering to the Greek Orthodox Church, in 1923.

The Gregorian calendar is thus seen to have served a considerable proportion of humanity over a relatively long and critical period of time. It would seem wise, therefore, before discarding or materially changing it to consider carefully whether the proposed changes may reasonably be expected to result in definite improvement. The calendar is too vital an instrument to be held lightly, or to be altered for the amusement or even for the benefit of a small group of enthusiasts or reformers.

As a first step in the process of arousing interest in any cause or proposed reform it is usually regarded as good practice to set forth the evils of the existing situation. So in this instance I shall begin by pointing out some of the defects of our present calendar. No attempt will be made to place these defects in the order of their relative importance, as such an arrangement would be largely a matter of personal opinion.

It is my purpose to treat the subject from the standpoint of the analyst rather than from that of the advocate of any particular plan or revision. It is probably inevitable, however, that my personal choice of a plan of revision will be indicated.

The principal defects of our present calendar may be listed as follows:

(1) The calendar year is of non-uniform length; ordinary years containing 365 days, and leap years 366 days.

(2) The calendar year is not evenly divisible into weeks, ordinary years containing 52 weeks and 1 day, and leap year 52 weeks and 2 days.

(3) The calendar year is not divisible, by months, into halves and quarters of uniform length.

(4) The months are of unequal length.

(5) The months are not evenly divisible into weeks.

(6) The date of Easter and other "movable festivals" is not fixed.

The above principal defects are more or less closely interrelated, and out of them flow a wide variety of secondary defects or inconveniences. For example, the first defect comes from the fact that the astronomical or tropical year does not contain an integral number of days. The length of the tropical year being slightly less than 365¼ days (365.2422 days, more exactly), it is apparent that if the calendar year is to contain an integral number of days the best that can be done is to make some years contain 365 and others 366 days. A more detailed discussion of the leap-year rule, and the length of the tropical year, will be found at a later point in this paper.

From the second defect, the fact that the calendar year is not evenly divisible into weeks, it follows that successive years begin on different days of the week. For example, 1931 began on Thursday, 1932 on Friday and 1933 will begin on Sunday. The two-day progression between January 1, 1932, and January 1, 1933, comes from the fact that 1932 is a leap year. The two-day

cember 31, it contained no January or February and (except in Scotland) no March 1 to 24, inclusive. 1752 was also a short year in Great Britain and her colonies, since 11 day-dates were dropped from the calendar in September of that year. There were no days designated as September 3 to September 13, inclusive, of that year. There was no interruption of the regular succession of the days of the week. Wednesday, September 2, was followed by Thursday, September 14. 1752 was a leap year under the new calendar, and if 1748 was a leap year under the old calendar, as it appears to have been, then these two leap years were separated by a period of only three years instead of the usual four years. That is, February, 1752, under the new calendar, contained 29 days, whereas, had the old calendar been continued, that month would have fallen in 1751 and would have contained 28 days only. It is thus seen that under the Gregorian calendar each leap year, beginning with 1752, has fallen one year earlier than it would have fallen had the old calendar been continued.

progression extends from February 29, 1932, to February 28, 1933, after which the progression of any given date through the week will be restored to one day per year, and this one-day progression will continue until again disturbed by February 29, 1936. A similar wandering, or progression, to various days of the week occurs, of course, for all other dates in the same way and for the same reason that it does for January 1.

This progression of any given date through the various days of the week is the cause of the ever-changing school schedules, vacation periods, etc., and it can be overcome only by some plan that will make all years begin on the same day of the week.

The third defect, *i.e.,* quarters of unequal length, comes from the fact that the months are of unequal length and irregular arrangement. In an ordinary year the quarters are as follows: First quarter, 90 days; second quarter, 91 days; third quarter, 92 days; fourth quarter, 92 days. This gives 181 days to the first half, and 184 days to the second half of the calendar year. In leap years, the first quarter is increased to 91 days and the first half year to 182 days.

The fourth defect, *i.e.,* months of unequal length, is the most obvious, and to many, the most serious defect of our present calendar. In childhood we learned that. "Thirty days hath September, April, June and November," etc., and by resorting to this rather cumbersome device we are able to decide as to the length of the various months. This inequality of the months makes direct comparison of monthly statistics impossible. Such statistics must be reduced to a uniform basis before accurate comparisons can be made.

The fifth defect, *i.e.,* the month not evenly divisible into weeks (except February of an ordinary year), is also generally recognized as a defect, and this also is regarded by some writers on calendar reform as of great importance. The question of its importance will be given further attention at a later point.

The sixth defect, *i.e.,* the wandering of Easter to various dates from March 22 to April 25, both dates inclusive, I shall not discuss in detail, except to say that the date of Easter and other movable church festivals can be fixed under a 12-month or a 13-month plan with equal facility. It is believed that the problem of selecting a suitable date for Easter, under the revised calendar, can safely be left to the properly constituted authorities of the several branches of the Christian Church.

Having pointed out some of the principal defects of our calendar, let us now consider what, if anything, can be done to correct or minimize these defects. In any proposed revision it is important that in our zeal for change we do not simply replace one defect with an equal or greater one. The only justification for changing anything that has served a large section of humanity long and satisfactorily is to secure something more satisfactory in its place; and since the function of a calendar is to serve as an accurate and convenient means of reckoning time and recording events, it follows that our only hope of securing a calendar more satisfactory than our present one lies in our ability to devise one that is more accurate or more convenient than the one now in use.

On the basis of accuracy our present calendar, as pointed out by Marvin,[4] is susceptible of slight improvement.

The passage of time, as indicated by watches and clocks, and by the calendar, is usually expressed in terms of the mean solar day and its subdivisions and multiples, the mean solar day being defined as the average time it takes the

[4] C. F. Marvin, *Popular Astronomy*, May, 1923, and "Standards Yearbook" (Bureau of Standards), 1929.

earth to make a complete rotation about its axis. As a matter of convenience, the calendar year is made to contain an integral number of mean solar days. It would obviously be inconvenient and confusing to have the calendar year begin at any time other than at the beginning of a day, *i.e.*, at 12 o'clock midnight.

The seasons are, of course, governed by the position of the earth with reference to the sun, and the tropical year is defined as the time it takes the earth to make a complete journey around the sun. This period is not divisible into an integral number of mean solar days. That is, in the time required by the earth to make a complete journey around the sun, the earth does not make an integral number of complete rotations about its own axis. This incommensurability of the tropical year and the mean solar day is the cause of much of the difficulty in calendar-making.

Length of the Tropical Year

According to mathematical astronomers the length of the tropical year is represented by Newcomb's equation, $L = 365\ d + f - b\ t$, in which f and b are constants having the values, $f = 0.24231545$, $b = 0.0000000614$, and t is the time in years counted from the beginning of the Christian era. On this basis the present length of the tropical year is 365.24220 days, and the year is growing shorter at the rate of 0.53 second per century.

Length of the Calendar Year

Since the calendar year contains sometimes 365 and sometimes 366 days, the average length is, of course, determined by the relative frequency of occurrence of these two numbers, that is, by the leap-year rule.

Under the Gregorian leap-year rule every fourth year is a leap year, except that of the century years only those years that are evenly divisible by 400 are leap years. That is, in a period of 400 years, 3 years that would normally be leap years, under the 4-year rule, are not counted as leap years. The average length of the calendar year under the Gregorian leap-year rule is, therefore,

$$\begin{aligned} L_{Gregorian} &= 365 + 1/4 - 3/400 \text{ days} \\ &= 365.24250 \text{ days} \end{aligned}$$

On comparing this value with the length of the tropical year, as calculated from Newcomb's equation, it is seen that the calendar year is longer than the tropical year at the present time by 0.0003 day, or 25.92 seconds. Moreover, if the tropical year is shortening and if it continues to shorten in accordance with Newcomb's equation, this difference will increase as time goes on and in the course of some 3,300 years from the time when the two were in agreement an error of a full day will have accumulated as a result of this increasing difference between the tropical year and the Gregorian calendar year.

Using Newcomb's equation to project back into the past, it is found that in 3006 B. C. the length of the tropical year was 365.24250 days. That is, at that time the length of the tropical year was the same as the average length of the calendar year under the Gregorian leap-year rule. The Gregorian calendar was, of course, not in use at that time, and by the time it was adopted, in 1582 A. D., the tropical year was already shorter than the Gregorian calendar year by some 24.3 seconds.

Because of this error in the average length of the Gregorian calendar year, as compared with the present length of the tropical year, it has been suggested by Marvin that in revising our calendar we should at the same time adopt a more nearly correct leap-year rule. A more nearly correct rule has, in fact, already been tentatively put into effect by the Greek Orthodox Church, which in its adoption of the Gregorian calendar did

not adopt the Gregorian leap-year rule, but in its stead, a more accurate one under which in a period of 900 years, 7 quadrennial years that would normally be leap years are not counted as leap years. Under this leap-year rule the average length of the calendar year is

$$L_{(Gk.)} = 365 + 1/4 - 7/900$$
$$= 365.24222 \text{ days}$$

It will be noticed that, to four decimal places, this value is in agreement with the present length of the tropical year.

Obviously, if the tropical year continues to shorten in accordance with Newcomb's equation this leap-year rule will, in the course of time, become incorrect even as the Gregorian rule has already become incorrect, and it in turn will need to be revised. However, it seems likely that before that time astronomers will have determined new and more exact values for the constants of Newcomb's equation, so that revision may be necessary on that account.

Various leap-year rules are discussed in detail by Marvin in the papers above referred to.

With further reference to the supposed necessity for adopting a more exact leap-year rule, it should, perhaps, be pointed out that this may be regarded by some as a case of "straining at a gnat and swallowing a camel," since even with a perfect leap-year rule the calendar and the tropical year are bound to be "out of step" by at least ½ day once in each 4-year period. For example, if the calendar year and the tropical year are "in step," that is, begin at the same time, at the beginning of a 4-year period, they will be "out of step" by ¼ day at the end of the first year, ½ day at the end of the second year, ¾ day (or ¼ day in the opposite direction) at the end of the third year, and again "in step" at the end of the fourth year. It may, therefore, be unwise to be troubled over-much by a cumulative error of one day in about 3,300 years. It might be just as satisfactory to correct the Gregorian leap-year rule by simply dropping out an extra leap year once in each 3,300 years. The average length of the calendar year would then be $365 + 1/4 - 3/400 - 1/3300$, or 365.24220 days. This value is in agreement with the present length of the tropical year, as calculated at an earlier point in this paper. The discrepancy that has already accumulated could be corrected by counting as an ordinary year some year in the near future, say 1940, that would normally be counted as a leap year.

Let us now turn to consideration of the second ground on which revision of our present calendar may properly be urged; that is, increased convenience.

The principal defects of the Gregorian calendar having already been pointed out, attention will now be given to means by which these defects may, in whole or in part, be overcome.

The many plans of revision that have been proposed, while differing in detail, are nearly all reducible to two general plans; first, the 13 equal months plan, and second, the 12 month, equal quarters plan.

The ideal arrangement would, of course, be a calendar year of 12 months, of 28 days each, since it would provide a complete and consistent series of time units, from the second to the year, with each unit containing an integral number of the next smaller unit.

The only difficulty with this plan is that it wouldn't work. Such a calendar year would be about 4 weeks shorter than the tropical year, and as a result, within a very few years, the 4th of July would come in the winter, and Christmas in the summer. There would be no fixed relation between the calendar and the seasons. Such a calendar would, of course, not be at all satisfactory.

We must, then, content ourselves with some plan that will keep the calendar

year as nearly as practicable equal to the tropical year, and at the same time be as convenient as possible.

We are, therefore, inevitably driven back upon one or the other of the two plans already mentioned; namely, the 13 equal months plan, or the 12 month, equal quarters plan. The practical problem is to decide which of these two plans will result in the greatest net gain, from the standpoint of convenience.

It has already been shown that the tropical year contains about 365¼ days, and that by the adoption of a suitable leap-year rule the average length of the calendar year can be made equal to that of the tropical year to any desired degree of approximation. Since it is important to have the beginning of the calendar year coincide with the beginning of a day, that is, to have the calendar year contain an integral number of complete days, it is obviously necessary to have some years contain 365 and others 366 days. In this respect there is no possibility of improvement through calendar revision, since the length of the tropical year and of the mean solar day are beyond the control of man. If they are "defective," from our point of view, it is unfortunate; there is nothing we can do about it.

The second defect of our calendar, that is, that the calendar year is not evenly divisible into weeks without a remainder, is the result of the simple mathematical fact that neither 365 nor 366 is evenly divisible by 7. There is a remainder of 1 day in ordinary years and 2 days in leap years, as already pointed out, and this excess of 1 day or 2 days is what causes the progression of any given date to various days of the week. The only way it can be overcome is by resorting to some device or subterfuge by means of which one week in each ordinary year and two separate weeks in each leap year are made to contain eight 24-hour periods each instead of the usual seven 24-hour periods. A wide variety of plans have been proposed for accomplishing this; "blank days," "double days" "days without date," etc. The usual, and most feasible, suggestion is that these 48-hour periods be placed at the end of December each year, and at the end of June in each leap year.

The method of designating the second 24-hour period of these suggested 48-hour "days" is not important, except that the designation must be definite and specific. They can not be "blank days" or "days without date," since events will occur, persons will be born, others will be married, still others will die during these 24-hour periods, as in any other similar period, and records must be as specific and definite as for any normal day. A satisfactory designation would seem to be "Sat. Dec. 31," this day to follow "Sat. Dec. 30," each year; and "Sat. June 31," to follow "Sat. June 30" of each leap year.

Obviously such a device would make the calendar year evenly divisible into weeks, with no remainder, and all years would then begin on the same day of the week.

If such a change should be put into effect at the appropriate time, say 1933 or 1939, all subsequent years would begin on Sunday and end on Saturday. Such a change would apply equally well to a 13 equal months calendar or to a 12 month, equal quarters calendar.

Objection has been raised by certain religious groups, notably Jews, Seventh Day Baptists and Seventh Day Adventists, to the adoption of any plan of revision that will interrupt the regular succession of the 7 days of the week. From the foregoing it is apparent that if a revision plan is to be adopted such that all years will begin on the same day of the week, whether it be a 12-month or

a 13-month plan, this objection, if it be an objection, will have to be tolerated.

The principle of the 48-hour period under a single day name is by no means new. At the time of Moses there were double days at the feast of the Passover. At the present time there is an almost exact analogy in the reckoning of time at the international date-line. When this line is crossed from west to east a second 24-hour period is given the same day-name (and date) as the 24-hour period just passed; that is, a day is repeated. On crossing the line in the opposite direction a calendar day is omitted. When a traveler from east to west passes from one standard time zone into the next he sets his watch back an hour and thus has two one-hour intervals in the period of one hour by his watch. These variations from the regular progress of time are not usually regarded as sacrilegious or in violation of divine law. They are regarded, rather, as convenient methods of bringing about standardization in the reckoning of time. It would seem that the proposed "double-day" might reasonably be regarded in the same light.

So far, then, there is no choice between the two proposed plans. With the third defect, we come to the parting of the ways, since what applies to one plan will not apply to the other. We must, therefore, decide which characteristics of a calendar are to be regarded as most important. For example, is it more important that all months be alike and each month evenly divisible into weeks, even though this arrangement makes necessary the addition of a new month; or is it more important to retain the 12-month calendar, to which we are accustomed, making the quarters equal, and the months as nearly equal as is possible under a 12-month plan?

Under the 13 equal months plan each month would contain 28 days, or 4 complete weeks, and all months would begin on Sunday. The calendar for all months would be as follows:

Sun.	Mon.	Tues.	Wed.	Thurs.	Fri.	Sat.
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28*

Note.—This arrangement is usually designated as the International Fixed Calendar.

* In order for all years to begin on Sunday, the last day of each year (Sat. Dec. 28), and the last day of some other month (*e.g.*, Sat. June 28), of each leap year, must contain 48 hours instead of the usual 24.

Under this plan a new 28-day month would have to be added at some point in the calendar. One suggestion is that it be inserted between June and July and that it be designated "Sol," as the summer solstice would fall within this period.

The most satisfactory arrangement for a 12 month, equal quarters plan, is undoubtedly that in which each quarter contains one month of 31 days followed by two months of 30 days each. This is often referred to as the "Swiss Plan," and more recently as the "World Calendar." Under the original "Swiss Plan" each quarter began on Monday and ended on Sunday, and the third month contained 31 days. The arrangement is shown on page 507.

It will be seen that the first month of each quarter, *i.e.*, January, April, July and October, begins on Sunday, contains 31 days with 5 Sundays and 26 week days, and ends on Tuesday; that the second month of each quarter, *i.e.*, February, May, August and November, begins on Wednesday, contains 30 days with 4 Sundays and 26 week days, and ends on Thursday; that the third or last month of each quarter, *i.e.*, March, June, September and December, contains 30 days with 4 Sundays and 26 week days, and ends on Saturday.

January
April
July
October

Su	M	Tu	W	Th	F	Sa
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

February
May
August
November

Su	M	Tu	W	Th	F	Sa
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30		

March
June
September
December

Su	M	Tu	W	Th	F	Sa
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30*

*In order for all years to begin on Sunday the last day of each year (Sat. Dec. 30), and the last day of June (Sat. June 30), of each leap year, must contain 48 hours instead of the usual 24.

Under this plan the four quarters would be equal, the two halves would be equal, corresponding months of each quarter and of all years would be equal, and for many industrial purposes all months would be equal, since each month would contain 26 week days. For certain other purposes the months would not be equal, since some would contain 30 and others 31 days.

Advocates of the 13-month plan lay great stress upon the importance of having all months of equal length, in order that for statistical purposes they may be directly comparable. It might be well to inquire whether making them the same length would in fact make them comparable. Obviously, because of seasonal variations, comparisons between December and June, for example, will, in many cases, be of little value, even though each month be made to contain 28 days. In many cases monthly statistical comparisons are valid only between corresponding months, for example, June with June, December with December, etc. Such comparisons are as convenient and as valid under the proposed 12-month plan as under any possible 13-month plan.

In general, statistical comparisons are made between periods recently closed and corresponding periods of former years. It is important, therefore, that current statistics be kept in terms of time intervals that have as nearly as possible exact counterparts in former years. For example, statistical comparisons can be made between August, 1931, and August of any other year without serious error. If correction is necessary in order to take account of the differences of industrial or business value of the different days of the week, this correction can readily be made. That is, if our calendar is revised on the basis of a 12-month, equal quarters plan, comparison of statistics for any month under the new plan, with those for the corresponding month under our present calendar, would not be seriously interfered with. Direct comparison of unreduced monthly figures for corresponding months would in many cases be satisfactorily accurate, and after the lapse of a few years, so that comparisons were entirely within the new calendar, they would be entirely accurate.

On the other hand, what would be the situation if we should adopt the 13-month plan? Corresponding months under the new calendar would, of course, be comparable; but what of comparisons between the new 28-day calendar months and corresponding periods of the past? Obviously, figures would not be available for corresponding periods of the past. How, then, could comparisons be made? The answer is that they could not be made without so many adjustments, approximations and assumptions that the comparative figures, when finally arrived at, would be of little value.

The case against the 13-month calendar from the statistical standpoint is well presented by Professor Clark Warburton in the closing paragraphs of his article in the August, 1931, number of the *Journal of Calendar Reform:*

> To re-compute the numerous indexes of prices, industrial production and other phases of economic activity would be a costly procedure justified only by definite and great advantages. In the case of many of the statistical series linking the present with the past, it would be impossible to convert the records of the past into a form comparable with the present.
>
> The next few years are certain to be critical years in the world's history. Economic changes are extremely rapid. Economic systems are challenging each other. There is great uncertainty. Popular clamor has begun for economic stabilization, for reform of the capitalist system so as to provide continuous and adequate incomes for wage-earners, and for the future development of productive facilities in accord with a national plan based on the needs and desires of the people.
>
> To meet this demand for business stabilization and for national economic planning it is essential that economists and business men have during the next few years all the aid possible from past business records. A radical change in the calendar would seriously reduce the usefulness of these records and thus hamper the adjustment of business to world needs at a critical time in the advance of civilization.

Another defect of our present calendar that is regarded by advoates of the 13-month plan as particularly serious is the fact that the month is not evenly divisible into weeks, so that, in general, the end of the month does not coincide with the end of the week. That this is a defect can hardly be questioned. It may, however, be questioned whether the defect can be overcome without at the same time introducing a still greater defect. If the remedy is worse than the disease, we might well prefer to suffer the disease to continue.

Under our present calendar the year consists of 52 weeks plus 1 day or plus 2 days, depending on whether it is an ordinary year or a leap year. As already pointed out it can be made to contain 52 weeks, with no remainder, by including one 48-hour period under a single day name in each ordinary year, and two such 48-hour periods, each under a single day name in each leap year.

The 52 weeks, or 364 days, may then be divided into months of whatever length is found most convenient. Under a 12-month plan the months can not be of equal length, since 364 is not evenly divisible by 12. The best that can be done is to have 8 months of 30 days each, and 4 months of 31 days each. The most satisfactory arrangement of these months, as already pointed out, is to have each quarter of the year contain one 31-day month, followed by two months of 30 days each. Under this plan the end of the month will coincide with the end of the week only at the end of each quarter; that is, at the end of each 13-week period.

The months can be made equal and at the same time each month made to contain an integral number of weeks, with no remainder, only by dividing the year of 52 weeks into months of 2, 4, 13 or 26 weeks each, since these are the only factors of the number 52. Of these possible divisions, the only one that results in months approximating in length those of our present calendar is that of 13 months of 4 weeks, or 28 days, each.

At first sight this seems like a reasonably satisfactory arrangement, and it no doubt would be if we were accustomed to it. The principal objections to it are (a) that it is too radical a departure from our present calendar to be readily accepted by the public; (b) that 13, being a prime number, can not be divided into sixths, quarters, thirds and halves, as can our present calendar year of 12 months. This would necessitate an extra closing of all books and accounts for business conducted on a quarterly or semi-annual basis, since the

ends of the first, second and third quarters would in no case correspond with the end of a month; (c) for statistical purposes the 28-day month would differ too much from our present calendar months, both in length and in seasonal position, to admit of accurate comparison with our present months; (d) the 13-month calendar would require an extra monthly closing of all accounts, reading of meters, sending out of bills, etc., and would thus add 1/12 to the clerical, postage and other such costs of doing business. (This is in addition to the cost of the extra quarterly and semi-annual closings already referred to.)

What advantages, if any, would accrue to offset these obvious disadvantages of the proposed 13-month calendar? There are two, and only two, that can not be attained equally well under a properly revised 12-month calendar. These are (a) the months would be made equal in length, and (b) the end of each month would coincide with the end of the week; *i.e.*, each month would contain an integral number of complete weeks.

But even these supposed advantages of the 13-month calendar are open to question. Even though all months be made of equal length they will still not be strictly comparable for many statistical purposes because of the number and distribution of holidays and because of seasonal variations. For example, a 28-day month without a holiday can not be said to be directly comparable, for industrial or business purposes, with a 28-day month having one or more holidays or with a 28-day month at some other season of the year. If an equalization, or reduction to the same basis, has to be made, even in the case of 28-day months, what, then, is the advantage of the 28-day month? It is no more difficult to equalize two months of 26 and 25 working days than to equalize two months of 24 and 23 working days, and in those cases in which equalization is not required, comparisons between two months of 26 working days would be as valid and as satisfactory as between months of 24 working days.

In the case of statistics of natural phenomena, such as rainfall, accumulated excess of temperature, etc., there would, of course, be an advantage in having all months of equal length.

Again, is it in reality important that the month be evenly divisible into weeks, so that the end of the month will in all cases coincide with the end of the week? Business may be conducted on a daily, weekly, monthly, quarterly, semi-annual or annual basis. The important consideration is that each unit of time be definite.

The same situation obtains with reference to units of quantity. We purchase some materials by the gallon, others by the cubic foot and still others by the pound. There is no more necessity that the month contain an integral number of weeks than that the cubic foot contain an integral number of gallons.

Employees are usually paid by the day, by the week or by the month, and each employee can usually adjust his financial program in such a way that income and outgo are properly balanced. Such difficulties as occur usually arise from the fact that the income is inadequate in amount rather than from the fact that the period of income is not exactly synchronized with the period of expenditure. In fact, it would appear that these two periods could be completely and exactly synchronized only by putting each individual, firm and corporation on a financial schedule similar to that of the average small boy, who, when he gets a nickel, spends a nickel; when he gets a dime, spends a dime; and when he gets a dollar, spends

a dollar. The general adoption of such a schedule would no doubt bring the period of earning and the period of spending into complete harmony, but, surely, making the end of the month coincide with the end of the week would have no marked influence in the matter. We should still continue to receive our income by the day, week, month, quarter or year, and to spend it in a manner highly irregular both as to amount and as to period of time.

Advocates of the 13-month plan of revision emphasize the importance of the 4-week period as a time unit for business purposes. If the 4-week period does, in fact, possess the advantages claimed for it, there would seem to be no reason why it should not be used for that purpose, by those who prefer it, without in any way interfering with the use of the 12-month, equal quarters calendar for other purposes or for all purposes, by those who prefer it.

SUMMARY

The Gregorian calendar is susceptible of improvement in the following respects:

(1) All years can be made to begin on the same day of the week. This can be accomplished equally well under a 12-month or a 13-month plan.

(2) A slightly more accurate leap-year rule than that now in use can be adopted if desired. There is some doubt as to the need for a more exact rule. If adopted it would apply equally well to a 12-month or to a 13-month plan.

(3) Under a 12-month plan the quarters of the year can be made equal by a slight adjustment of the lengths of certain months of the Gregorian calendar.

(4) The months can be made equal for many industrial purposes, and corresponding months can be made equal and comparable for all purposes, under a 12-month, equal quarters plan.

(5) All months can be made equal by the adoption of a 13-month plan.

(6) Each month can be made to contain an integral number of weeks by the adoption of a 13-month plan.

(7) The date of Easter and other movable church festivals can be fixed equally well under a 12-month or a 13-month plan of revision.

(8) The 4-week period can be used for business purposes, by those who prefer it, without interfering with the 12-month calendar.

FOUNDATIONS OF THE FACE

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I

IT is said, "There is no art to find the mind's construction in the face." It is true, the visible evidence of surging emotions and desires may be concealed and the intensity of dominant motives temporarily modified. But, speaking in terms of evolution, bodily and mental constructions are different aspects of the same vital process. For man may surely, though dimly, see in his own face the constructive results of the ruling motives and desires of a long line of animal ancestors, modified by the urgings and prohibitions of environmental influences. And if he so desires, he may find in the features of all his fellow creatures something of the history of their combined physical and mental achievements.

The face is a fortified and a highly discriminating portal to internal privacy. There the chief inspectors and appraisers of vital commodities are assembled, and their structure and behavior is the surest indication of the dominant purpose of the whole complex of bodily and mental activities that we call life. On the other hand, the superb art and the constancy of purpose that is so manifest in the construction and behavior of all living things, in their perpetuation and in their development, individually and socially, is the only clue we have to the "construction of the mind" in either man or nature.

Practically all plants and animals are "made" in unlike pairs, called males and females. This structural dimorphism, called sex, is the outward indication of many complementary functions for the evident purpose of reproduction, and for providing the renewed life with adequate rations, guidance and opportunities for further life and growth. These internal reproductive faculties are supplemented by a great variety of external agencies that have their origin in cosmic, terrestrial and social environments.

Non-living things, such as water, crystals, suns and stars, never have this cooperative sexual duality, nor the ability to reproduce and provide for themselves. They arise intermittently, or *de novo,* from more universal reproductive agencies.

The great community of plant and animal life has grown up slowly, but continuously, within the nutrient shelter of its mother earth, itself the offspring of fertile cosmic agencies. And throughout the geologic ages, all this life has necessarily grown up in essential conformity with the opportunities, the limitations and the demands of its native residence.

In a similar way, every individual plant or animal now grows up from an egg or germ, within the shelter of parental envelopes of some sort, and by means of the nourishment and guidance, bodily and mentally, prepared for it beforehand by its forebears. In other words, all parents and all offspring, dead or alive, constitute one self-provisioning and self-perpetuating organism.

The long sequence of divergent, hesitating steps in the evolution of life is evidently the responses of life to structural and functional innovations of different creative value. In accordance with their potential value, they become

relatively fixed or permanent, and so lay the foundations for further adventures in the art of living. All such innovations come from no one time or place, but from a measureless blue of latent potentialities. They apparently produce the more pronounced fluctuations, or mutations, in the rate, the direction and the fruitfulness of evolution, which in perspective mark the gaps, great and small, in our knowledge of life. Thus our disjointed classifications of natural phenomena, our rigid formulas, graphs and pictorial diagrams of living animals, are but rows of dots summarily indicative of recognizable currents in an endless ocean of otherwise unexplored activities. Thus our crude biological diagrams are to be regarded as four-dimensional mathematical formulas, rather than pictures of any one living thing.

The familiar terms heredity, natural selection and evolution are so artificially restricted and so befogged with technicalities that their real significance is not duly appreciated.

The implications of these four-dimensional figures of speech are inseparably interwoven with one another. They clearly imply that the more helpful, or useful ways of living, germinally, individually and socially, in some mysterious but ever-insistent way, actually are perpetuated and increased, and that the less helpful, or no longer useful ways, are not. They clearly imply that there is a universal trend, purpose or objective in the lawful activities of nature, a vital purpose which is visibly expressed in the successful operation of a moral and ethical method of self-preservation, growth and evolution. It is the rightness of this method which all of us, consciously or unconsciously, are striving to imitate, and to utilize scientifically and artistically, and for the same purpose.

II. Standard Patterns of Cellular Organization

Cells are basic units of life, definitely standardized in form and action. They are to the biologist what atoms and molecules are to the chemist, or what human beings and their social aggregates are to the statesman.

When multiplying cells form multicellular bodies, such as a jellyfish, a worm or a human being, they are always arranged in relatively fixed structural patterns expressive of the various functions they perform for the common welfare. There are not more than half a dozen basic patterns of this sort, such as spherical, branching, spiral, etc. The bodies of all the higher animals, such as certain worms, insects, crabs, fishes and man, are built on a jointed, bilaterally symmetrical pattern, called the triaxial system. They all start from an initial germ cell planted in a more or less spherical mass of food yolk; they then grow up in three main directions, lineally, transversely and radially, thus forming six-sided bodies with what we call a head end, tail end, dorsal and ventral surfaces, and with symmetrical right and left sides. Hence no two points or cells in such a body are ever exactly alike in respect to age, relative location, structure and opportunity.

This highly standardized method of cell growth produces the maximum diversity of bodily organs; and also the best arrangement of them for the internal business of life and for the adaptive adjustment of the body as a whole to the external world. No other method of self-construction is so pregnant with creative possibilities.

The lower kinds of triaxial animals may consist of a great many body joints, or metameres, most of them with a full complement of the essential organs of life. But this multiplicity of similar functions is unduly extravagant,

or cumbersome, and eventually many local improvements arise which serve the main purpose of life more effectively. That is, certain kinds of organs, nervous, sensory, glandular, motor, etc., develop the more in those places where they can best perform their bodily functions, while others disappear or perhaps take on new functions of a very different nature.

In the higher invertebrates, this type of bodily organization settled down, something like a thousand million years ago, into three different sub-patterns, such as those in insects, crustacea and arachnids. That is, all insects and their offspring are built on one of these patterns, all crustacea, crabs, lobsters, etc., on a little different pattern, and all arachnids, such as spiders, scorpions, etc., on still another. It is by their underlying patterns that we are able to recognize them as such, in all their multitudinous varieties now and in past geologic ages.

The arachnid pattern is the only invertebrate pattern which resembles that of man and all the other backboned animals. This resemblance is shown in many ways, too numerous, too peculiar and too constant to be accidental, or what is vaguely called a "mere parallelism." It is seen in the subdivision of the first sixteen or more body joints into five main groups, each one with approximately the same number of joints, the same kind of sense organs, ganglia, nerves, muscles, cartilages, glands, etc. And all these animals arise from the egg in a similar fashion, and make their appearance in past geologic ages in a duly corresponding sequence. This mutually confirmatory evidence of comparative anatomy, embryology and paleontology, according to all the canons of the biological sciences, clearly indicates that man and all his vertebrate predecessors had their origin in a very ancient arachnoid stock, something like a thousand million years ago, and that the fundamental pattern of bodily organization common to all of them has not changed in any essential respects since that time.

This pattern of bodily organization is unique. But like other "types" of living things, it is a chequered, fixed and fluid pattern that periodically appears and disappears, that adjusts and readjusts itself to changing environments, yet still remains the same old pattern.

The advantages of the triaxial method of growth over any branching, spherical or spiral method are obvious. But in what respect the arachnid pattern is any better than that of mollusks, insects or crustacea is not at all evident. Nevertheless, it is clearly evident, I believe, that on that particular foundation all the elaborate structure of fishes, reptiles and mammals have been progressively upbuilt, and that in it are resident the tremendous potentialities of human life.

According to this view, therefore, the first sixteen or more body joints of the arachnids eventually united to form the head and face of man and other vertebrates. The "head," in this technical sense, is the most complex structure known to the biologist. During the last hundred years, or more, innumerable attempts have been made to analyze and interpret its various parts, but all of them have ended in barren and apparently hopeless controversy. Now that we have definite assurance of the kind of animals from which the vertebrates arose, a master key to all such problems is available.

III. Foundations of the Backbone and the Skull

In body building, a good roof and a firm central axis are primary requisites. A skull to protect the brain, and a jointed backbone to enclose the spinal cord and give rigidity and flexibility to the body as a whole, fulfil these require-

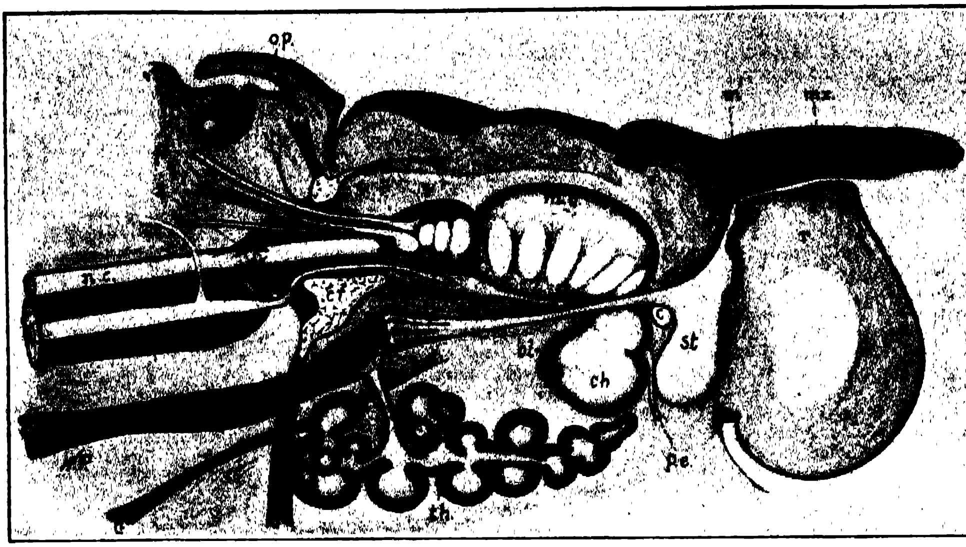


FIG. 1. MEDIAN SECTION OF A LARGE JAVANESE SCORPION (HETEROMETRUS CYANEA)

SHOWING THE FOUNDATIONS OF VARIOUS ORGANS IN THE HEAD AND FACE OF MAN. THE SKULL, OR ENDOCRANIUM, *cr*; THYROID GLAND, *th*; AND STOUT FIBROUS BANDS, *s*, BY WHICH THE NOTOCHORD, *nt*, IS FIRMLY ATTACHED TO THE FLOOR OF THE ENDOCRANIUM.

ments in all the higher animals from fishes to man, and provide the framework for the more elaborate details of the head and face.

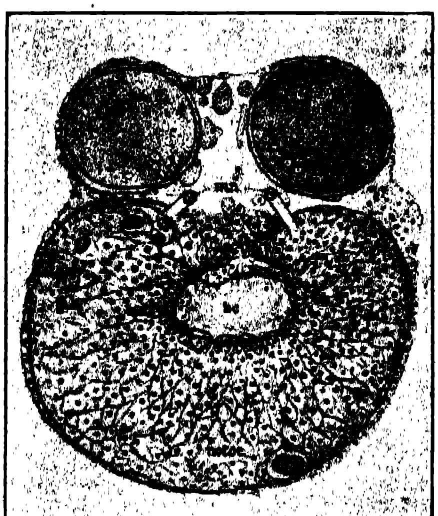


FIG. 2. THE FOUNDATIONS OF MAN'S BACKBONE.

THE NOTOCHORD OF A JAVANESE SCORPION IN CROSS SECTION. BLOOD CHAMBER, *bc*; MEDIAN NERVE, *mn*, ROOTED AT INTERVALS IN THE NOTOCHORD, AND IN THE GANGLIA OF THE CORD.

But the backbone is always upbuilt, embryologically, around an unjointed rod called the notochord, which is evidently a far more fundamental structure than the backbone itself. And so the notochord and the primitive cranium have been the themes of endless investigations and speculations as to their methods of development, their initial functions and the kind of animals in which they arose.

In spite of all these investigations, no worm, insect, crustacean or any other invertebrate shows any traces of the presence of both of these structures at the same time, except the arachnoids. There, as shown in a median section of a large Javanese scorpion (Fig. 1), both of them are present in their characteristic forms and relations, together with very definite evidence of their initial functions. From such evidence, it is clear that our skull was, primarily, a cartilaginous framework for the attach-

ment of powerful muscles which moved, hingelike, the primitive head (cephalothorax) on the body.

The notochord was a cylindrical rod, containing a median nerve and a blood channel, heavily invested with lymphoid supporting tissues (Fig. 2). This primitive ridgepole of our body was stiffened, in the early vertebrates, with many cartilaginous hoops and props which eventually united and changed into bony vertebrae (Fig. 3). Within them are now enclosed the spinal cord, together with the last remnants of the notochord and the median nerve of our arachnoid ancestors (Fig. 3).

IV. The Old Mouth and the New

In all the invertebrates, such as worms, insects and scorpions, the mouth is the external opening of a very ancient passage way (stomodaeum) through the floor of the brain into the main alimentary canal.

Here, the architect of our destiny seems to have blundered in locating the front door of the body in such an inconvenient place. At any rate, the increase in the volume of the forebrain region, which inevitably accompanies the higher stages of life, tends to constrict this ancient gateway to the gut, and thus to cut down the influx of nutritive materials. For that reason, many of the invertebrates, and especially the arachnoids, are obliged to live on a liquid diet sucked through a pinhole corridor in the floor of an overgrown brain (Fig. 1).

In this scorpion, for example, the mouth is a minute pore, m′, completely covered up by rigid spurs or maxillaria. But on the under side of the spurs, on the fourth pair of legs, is an elaborate network of capillary canals through which the juices of their prey were slowly pumped into the mouth and through the floor of the brain into the main alimentary canal.

This was a serious administrative problem for our scorpion-like ancestors. For the bigger their brains, the less they could eat. Moreover, all the tendencies of bodily growth seemed to conspire for the closing up of this opening. Apparently there was but one way out of this impasse in the evolution of two equally essential functions. And, strangely enough, that way was already prepared in the form of an obscure opening into the gut on the opposite side of the head, called the dorsal organ, or cephalic navel (Fig. 9A).

This opening offered an opportunity for a more direct and unobstructed passageway into the alimentary canal, and eventually it became the mouth of man and of all the other vertebrates.

This old trapdoor through the floor of the brain (infundibulum) still remains as a conspicuous cerebral landmark which has long been known to the surveyors of vertebrate brains. But its

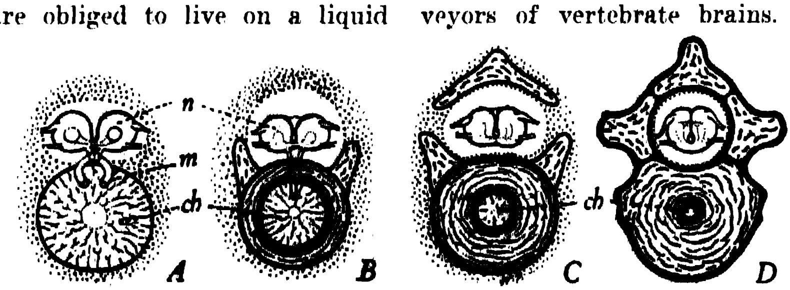


FIG. 3. DIAGRAMS OF SUCCESSIVE STAGES IN THE EVOLUTION OF THE BACKBONE.

Scorpion, *A*. Fishlike vertebrates, *B.C*; man, *D*. Notochord, *ch*; median nerve, *m n*; spinal cord, *n*.

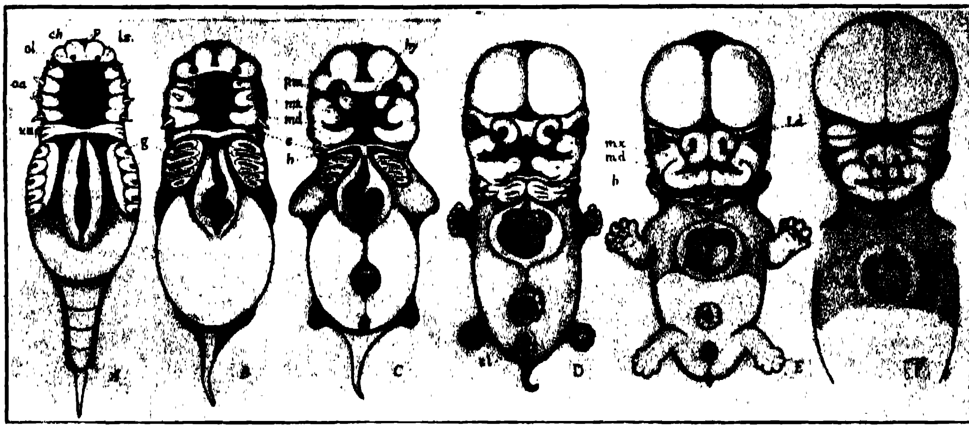


FIG. 4. DIAGRAMS OF VARIOUS STAGES IN THE EMBRYONIC DEVELOPMENT AND THE EVOLUTION OF THE BODY AND THE FACE,

FROM THE ARACHNIDS, *A*, TO MAN, *D,E,F*. STAGES *B* AND *C* ARE LARGELY HYPOTHETICAL, BUT THEY ARE BASED ON KNOWN CONDITIONS IN FISH-LIKE VERTEBRATES, AND ON THE ARRANGEMENT OF ORAL ARCHES IN THE OSTRACODERMS. *e*, EAR; *ch*, CEREBRAL HEMISPHERES; *cl*, CLOACA; *g*, GILLS; *h*, HYOID ARCH; *ht*, HEART; *hy*, HYPOPHYSIS; *md*, MANDIBLE; *mx*, MAXILLAE; *n*, NAVEL; *p.mx*, PREMAXILLAE; *t.d.*, TEAR DUCT; *v.a.*, VAGUS, AUDITORY AND HINGING METAMERES.

origin and its significance was unrecognized. In man, it is entombed by overhanging cliffs of bone, and overgrown by forests of tangled tissues. But there it stands, reproduced generation after generation, as one of those living ruins of primordial life which man so unwittingly carries about with himself (Fig. 9).

The formation of a new mouth, probably in the Cambrian or some Precambrian era, was one of the most fruitful and dramatic events in the history of organic evolution. It revolutionized all the existing functions of life and gave rise to the greatest variety of aberrant forms ever produced in any one geologic era. It also laid the corner-stone for the longest sequence of evolutionary stages, from class to class, known to the biologist.

It was, therefore, a structural innovation of supreme functional value. Like all such innovations, it temporarily accelerated the rate and diversified the products of evolution. It inevitably produced one of those great mutations or, in perspective, one of those apparent gaps in the march of evolutionary processes, which are always so baffling to the biological historian. And the great variety of new kinds of animals which so suddenly appeared on the horizon, many of them crippled and degenerate, or imperfectly adjusted to the new conditions of life, greatly added to his confusion.

V. The New Face and the Oral Arches

The formation of a new mouth and the convergence around it of six pairs of oral arches marks the beginning of a new fashion in faces. The series of diagrams in Figs. 4 and 9 will help us to visualize some of the stages in the evolution of these modern faces, starting with the fashion in scorpions and fishes, and leading up to the most modern fashion in man. Every bodily organ is involved in these changes, but the fundamental pattern of bodily organization remains essentially the same.

The principal events here illustrated are the progressive transformation of the jaws, gills, brain and heart; and

that of the great cephalic sense organs, visual, olfactory and auditory. The larynx, the main instrument of articulate speech, is eventually formed from remnants of the old gill arches. The march of these events is dominated by the great volume and the precocious development of the brain and the heart and by that of the nutritive and excretory systems. Their priority is expressive of some of the more fundamental requirements of bodily developments.

There are several notable centers of construction toward which certain groups of organs and their tributaries converge and eventually unite; namely, the mouth, the larynx, the heart, the belly button, and the cloaca, or the main outlet of the genital, urinary and alimentary organs.

The principal stages in the evolution of the face from fishes to man are well known to the biologist, but no adult stages between fishes and their invertebrate ancestors have been found. We have now discovered, I believe, conclusive evidence of this sort in an obscure group of extinct animals called the Ostracoderms. Their fossilized remains are very rare and always fragmentary, but it is quite certain that once upon a time, long before the true fishes came into existence, they formed a large and highly diversified class of animals, different in many important respects from any other class.

We maintained, more than forty years ago, that the Ostracoderms were the "connecting link" between the vertebrates and certain arachnoid animals, such as the giant sea scorpions, which in the days of their prime were the highest animals in existence and the so-called "rulers of the seas." The new specimens of Ostracoderms confirm this interpretation. Some of them were obtained on my last expedition to the Island of Oesel in the Baltic Sea. A brief report appeared in the *Dartmouth Alumni Magazine*, June, 1931, and in *Science* for June 19, 1931; and some of the specimens were exhibited at the New Orleans meeting of the American Association, in January, 1932, and at the New York meeting of the Anatomists in April, 1932. A full description of them will appear later.

The Ostracoderms are of special importance, in that they show us some of the most significant stages in the construction of modern faces. They illustrate what may be regarded as tentative trial adjustments of the oral arches, jaws or gnathites, around the new

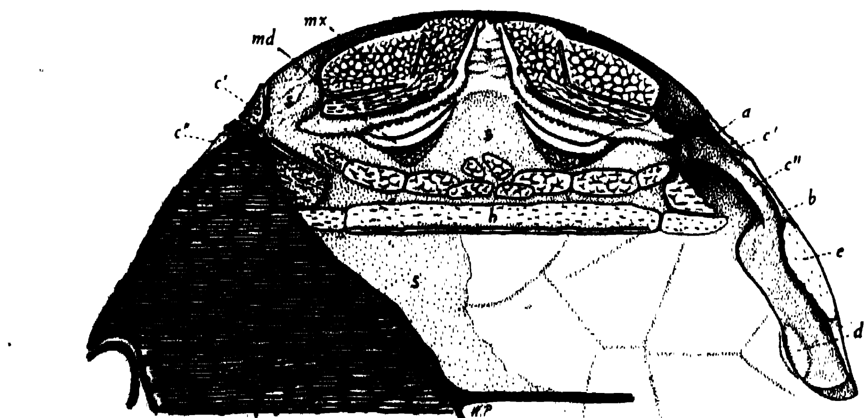


FIG. 5. THE FACE OF AN OSTRACODERM (BOTHRIOLEPIS) FROM CANADA

UPPER DEVONIAN. RIGHT SIDE PARTLY REMOVED. *h*, HYOID ARCH; *md*, MANDIBLES; *mx*, MAXILLAE; *c'*,*c''*, CHEEK PLATES; *s*, SKIN.

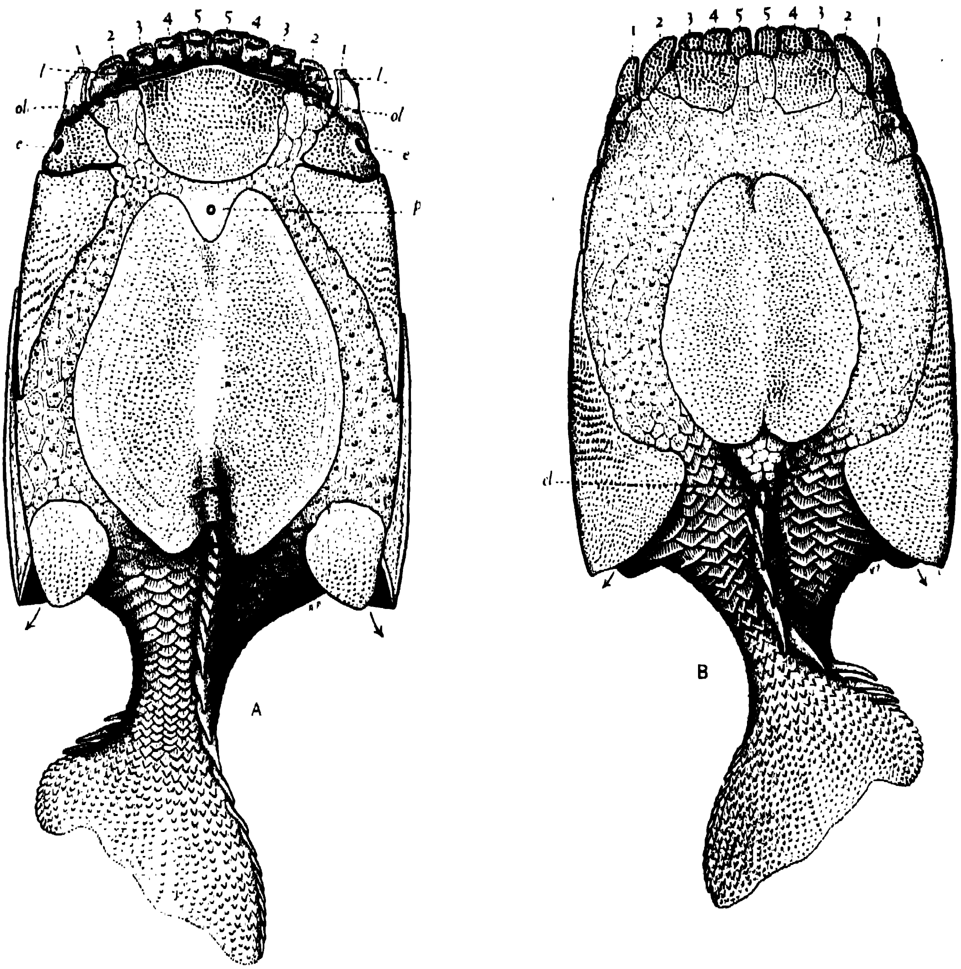


FIG. 6. AN OSTRACODERM (DREPANASPIS) FROM GERMANY; MIDDLE DEVONIAN. *A*, DORSAL SIDE; *B*, VENTRAL SIDE; *cl*, CLOACA; *e*, LATERAL EYE; *l*, LABIALS; *ol*, OLFACTORY PIT; *p*, PINEAL; 1–5, ORAL ARCHES, OR GNATHITES.

mouth, before they finally settled down into the standard facial combinations so characteristic of the higher vertebrates. At least three kinds of Ostracoderm faces are now known. They all look extremely grotesque, for externally they are indeed very different from any animals with which we are familiar.

In one type (Drepanaspis) from the lower Devonian of Gemünden am Rhein, four or five pairs of jaw-like oral arches are present (Fig. 6). They are covered with bony plates and project forwards, beyond the upper side of the head, to form a stiff lower "lip" to an enormous scoop-shaped mouth. Each of the four central arches ends in a rounded dental cusp. It is certainly a very poor kind of face, but these animals managed, nevertheless, to make a living with it by scooping up starfishes and other similar animals from the bottom of the sea, as is clearly shown by their fossilized excrements, which are spiral clumps of calcareous spines.

The second type (Bothriolepis, from

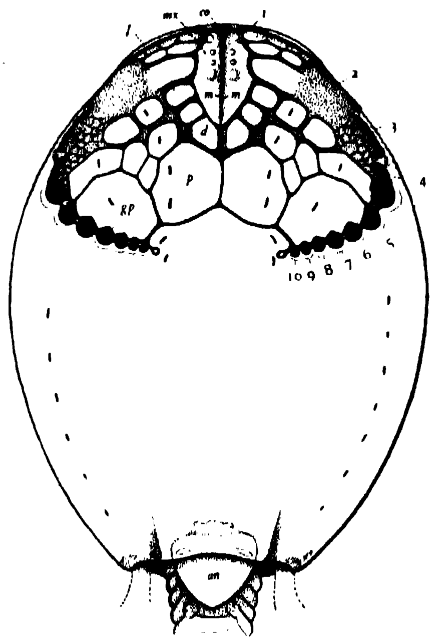


FIG. 7. HEAD AND FACE OF AN OSTRACODERM (TREMATASPIS SCHMIDTI)

FROM THE ISLAND OF OESEL. SILURIAN. *co*, ORAL CUSHION; *g.p*, GILL PLATE; *l*, RAISED MARGIN; *m*, SLIT-LIKE MOUTH; 1–10 SEGMENTAL INCISIONS IN THE SHELL-LIKE COVERING.

the upper Devonian of Canada) is more like the standard condition seen in true vertebrates (Fig. 5), that is, the oral arches lie in a transverse direction instead of a longitudinal one. Here, as I first described many years ago, there are four rows of plates, probably representing various parts of four pairs of oral arches. One represents the maxillary arch and another the lower jaw. But they have not grown together across the median line, as in all true vertebrates. Hence these animals have to chew their food sidewise, and by other very complicated facial movements. The folds of skin, s, between the crushing edges of the maxillae, and between the points of the mandibles, clearly indicate the way they act and the location of the mouth.

They usually live in shallow inland waters and feed on soft fern-like water plants, as shown by the purely carbonaceous contents of their stomach, or intestines. The so-called "operculum," c, is not a movable gill cover, for it is firmly locked on three sides by stout overlapping sutures and internal processes, a, b, c, d. The gills lie behind the auditory vesicles and open with the cloaca into a common peribranchial chamber. Hence the great swimming arms are certainly not pectorals, but probably true cephalic appendages, like those of the giant sea scorpions.

The third type is represented by Trematapis, and other Cephalaspids, from the Island of Oesel. Trematapis lived in the Silurian age. It is one of the oldest of all the Ostracoderms and therefore has special significance for us. Its remains are very fragmentary, and heretofore only a very few imperfectly preserved specimens have been found.

The specimens obtained on my last expedition clearly show that Trematas-

FIG. 8. HEAD OF TREMATASPIS.

THE ORAL PLATES HAVE BEEN REMOVED, SHOWING THE BROAD, FLATTENED FLOOR OF THE CRANIUM, *c*; PARTS OF THE EAR, *e*; THE OLFACTORY-HYPOPHYSEAL TUBE, *h*; LATERAL EYES, *a*; THE ENDS OF FOUR ORAL ARCH BARS, *b*, 1–4; AND THE POST BRANCHIAL SEPTUM, *p.s*.

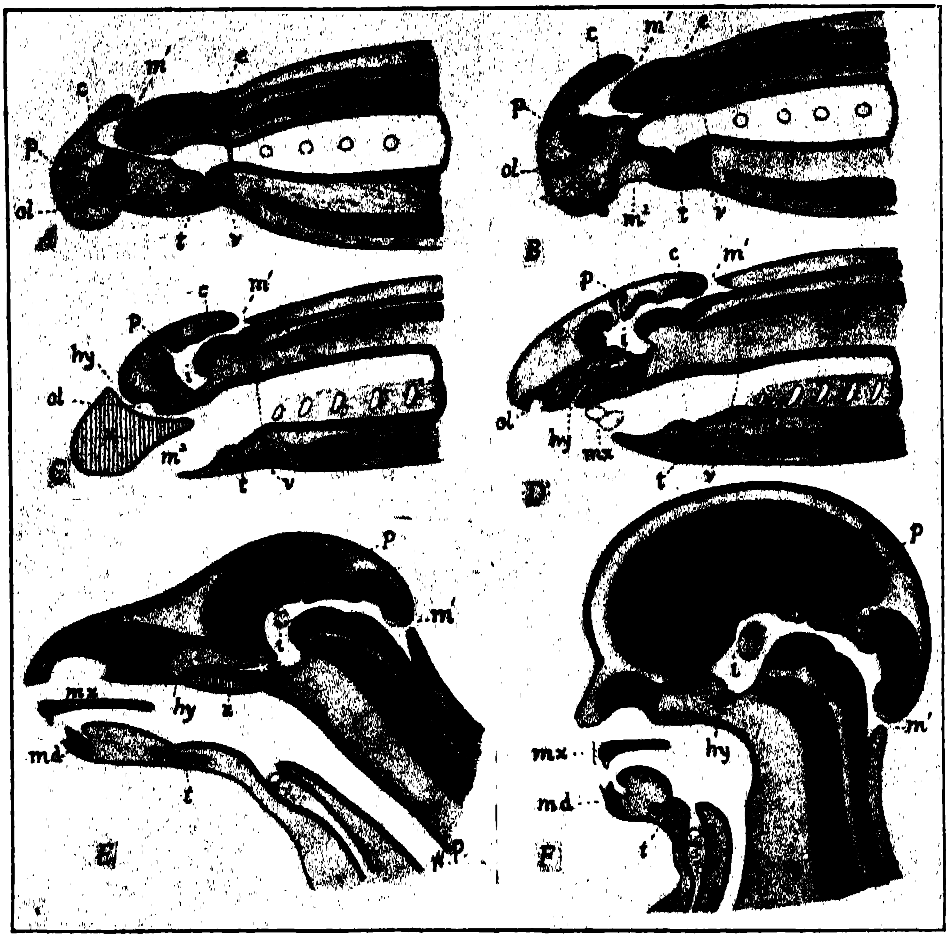


FIG. 9. DIAGRAMS, IN LONGITUDINAL SECTION, SHOWING THE FOUNDATIONS OF SOME OF THE IMPORTANT ORGANS OF THE HEAD AND FACE

FROM SCORPION-LIKE ANIMALS, *A&B*; PRIMITIVE FISHES, *C&D*, AND MAMMALS, *E*, TO MAN, *F*. *c*, CEREBRAL HEMISPHERES; *e*, EAR; *hy*, HYPOPHYSIS; *i*, INFUNDIBULUM; *m'*, PRIMITIVE MOUTH; *m''*, NEW MOUTH; *mx*, MAXILLAE; *md*, MANDIBLES; *n*, NOTOCHORD; *ol*, OLFACTORY ORGAN; *p*, PINEAL EYE; *t*, THYROID; *v*, VAGUS AND PRECARDIAC SEPTUM; *x*, PRE-OLFACTORY ROSTRUM AND ETHMOIDAL CUSHION.

pis, in the adult stages, has at least four pairs of preotic and prebranchial oral arches, covered with bony plates (Fig. 7). The mouth is a median longitudinal slit flanked by heavy jaw-like structures, which in chewing worked transversely, not forwards and backwards, as in typical vertebrates.

When these covering plates are removed, the various parts of four distinct preotic and prebranchial metameres are revealed, including bony spurs for the attachment of oral arch muscles, various openings for blood vessels and nerves, and shallow grooves for corresponding gut lobes (Fig. 8).

It now appears, from the above evidence, and other evidence that we can not go into here, that six pairs of thoracic arches of the arachnoid type

were involved in laying the foundations of our face. The first one or two pairs, carrying with them the adjacent olfactory placodes and other tissues of a glandular nature, first united at the very anterior end of the head to form the infolded roof of the mouth (Figs. 6 and 9, A, B, C). It may well be that the olfactory-hypophysial canal, hy, thus formed in primitive Ostracoderms and in the Cyclostomes, served as a makeshift mouth, while the other arches, premaxillae, maxillae, mandibles and hyoids, were assuming in a somewhat similar manner their final arrangements.

Meantime it is significant that the made-over remnants of the oldest recognizable structures in this long series of animals were assuming the extraordinary functions of regulating the multitudinous activities of the body as a whole. These very ancient organs in their new disguise are the so-called ductless glands. The structural foundations of them, especially the pineal gland, the pituitary complex and the thyroid, were laid down with those of the head and face in our arachnoid ancestors, and they now play a conspicuous rôle in our facial expressions.

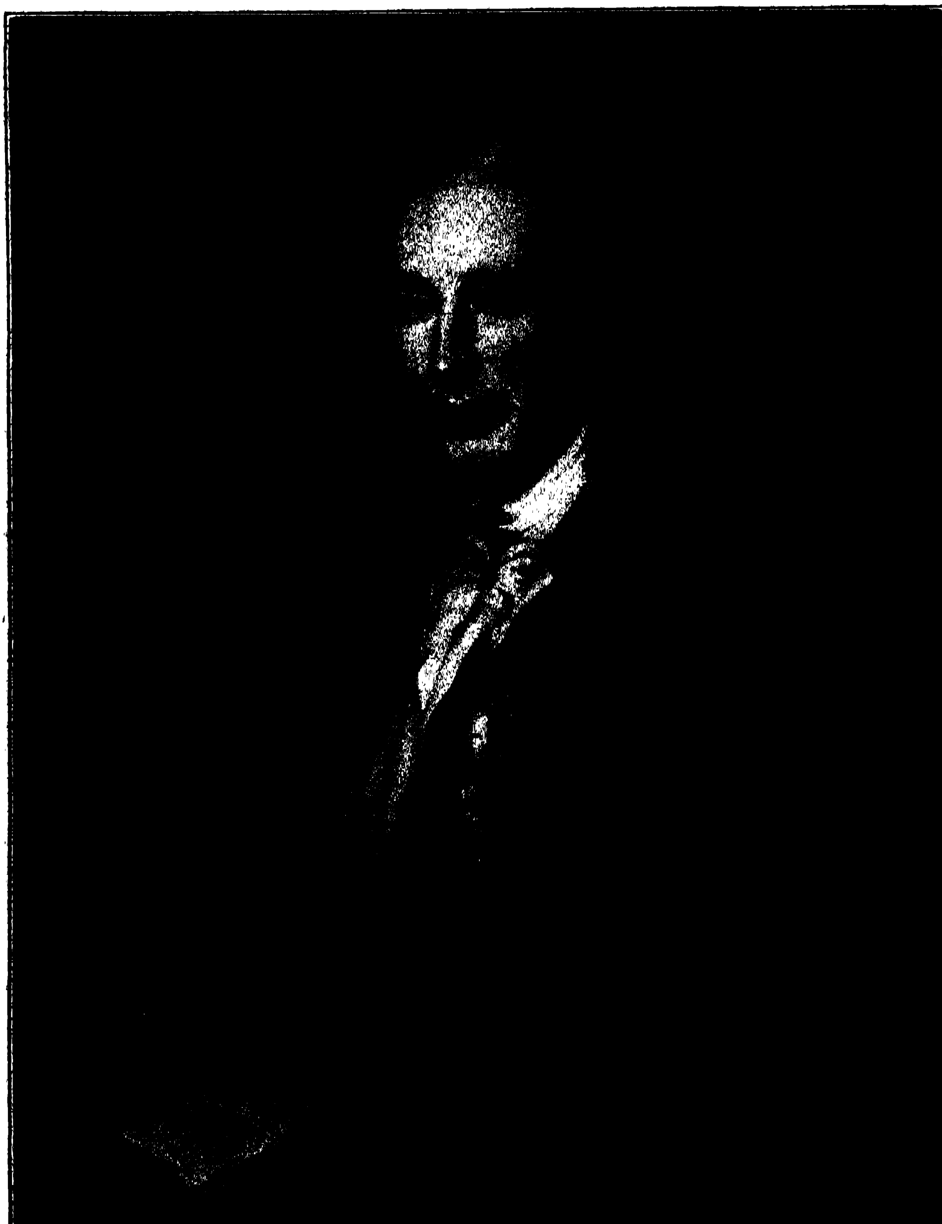
As I have said in the *Dartmouth Alumni Magazine:*

> All this is not merely a new bit of evidence for evolution. It will require new interpretations of many anatomical and embryological data, and far reaching readjustments of our philosophy of evolution. We biologists are commonly content to point out this or that path which evolution has taken in the past, or may take in the future, but we have very vague ideas as to the relative values of the parts played by heredity, by environments, and by individual organisms.
>
> But here, it seems to me, we have the most impressive picture of the creative power of a specifically constructed organism that science gives us. For this initial pattern of bodily structures and functions dominates the whole sequence of evolutionary processes from sea scorpions to man. Environments, heredity, and natural selection are essential to the realization of its inherent potentialities, it is true, but they have made no radical changes in the pattern itself, for something like a thousand million years.
>
> There is no other known sequence of natural phenomena so vast, so complex, and so precisely determined in its inception, in the course it follows, and in the fertility of its results. Mankind has grown up out of this scorpion-like germ from an immeasurable past, with the same marvellous precision that to-day a new human being grows up from a specially constructed egg or germ cell. To the biologist who really sees and feels these things, the age of miracles—real honest-to-god miracles—has not passed away.

And so it should not be forgotten that all evolutionary phenomena are fundamentally inexplicable. Atoms and protoplasmic cells, wavelets and bullets of energy, kingdoms and principalities of plant and animal life, by themselves alone have no significance, and no measurements, comparisons, or enumeration of them will give us any real explanation of their origin or their magic performances. We see all these mysterious rabbits come out of a magic hat. That is all. The sequence, and the source, are the only clues to understanding.

The most significant discovery of modern science is that this furious mob of heterogeneous agencies, in some wholly unimaginable way, really does flow methodically and imperturbably in the mutually self-perpetuating ways of life and evolution.

The amazing performance proceeds, openly and regularly, yet no one can see how the trick is done. But we suspect there is some sort of collusion between the Magic Hat and all these goddam rabbits.



DAVID RITTENHOUSE

THE LILY PORTRAIT, BY CHARLES WILSON PEALE, PAINTED FOR THE AMERICAN PHILOSOPHICAL SOCIETY, SO CALLED BECAUSE OF THE LILY-LIKE RUFFLE UNDER HIS STOCK.

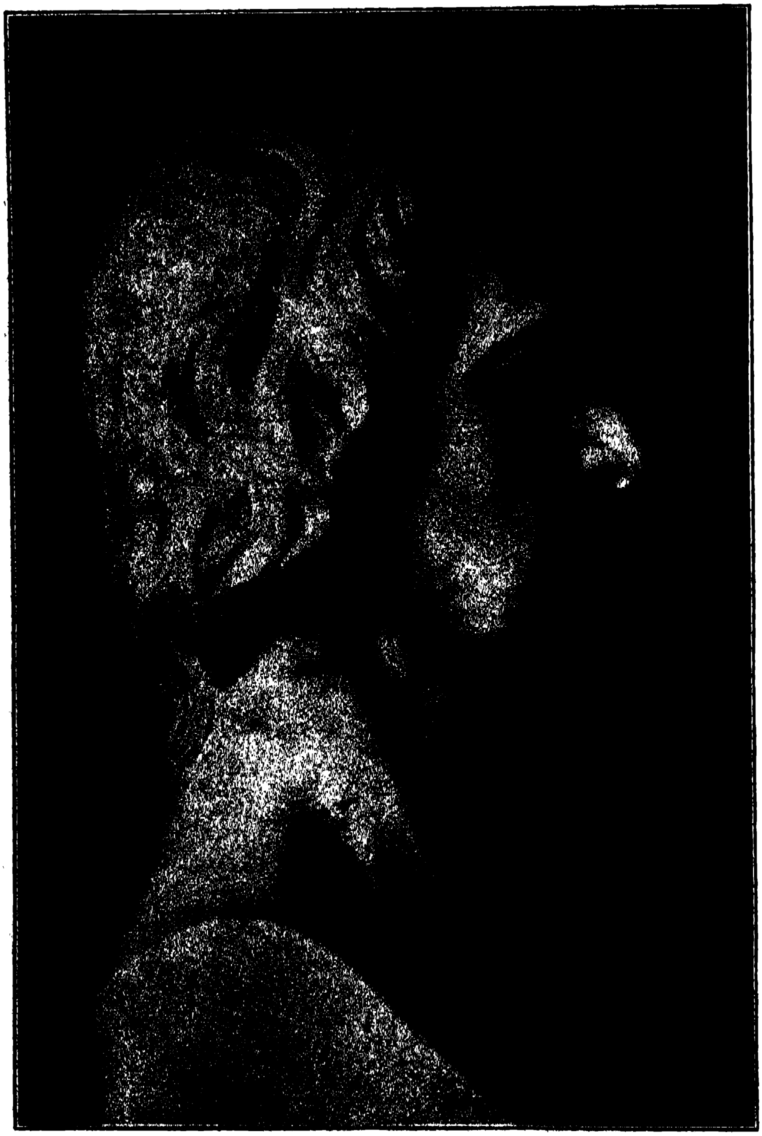
THE DAVID RITTENHOUSE BICENTENARY

By Dr. M. J. BABB
DEPARTMENT OF MATHEMATICS, UNIVERSITY OF PENNSYLVANIA

The Ancient Greeks had three problems which they were unable to solve with their specified tools—the compass and the straight edge. Modern mathematics has shown that they might have limited themselves to one or the other tool. The three problems were: to find the area of a circle, to duplicate a cube and to trisect an angle. The whole of Greek geometry was invented as a by-product without accomplishing the solution of any of these problems, and modern mathematics has shown that all three are impossible with the implements specified, though every year solutions are promised by men otherwise honest and honorable, the last one of these fallacies having been issued within a year by the head of a recognized school of a great church.

Modern mathematics also has many problems. I will mention three of them; the first one you may play with at your leisure. If you were drawing a map of Europe or the United States or the counties of a state or the township of a county how many colors would you have to use in order to make the boundaries distinct? Would four do, or can it be done with less? A second; we know three squared plus four squared equals five squared. Do any other like powers of two different integers sum to the same power of another integer? The other problem I want to mention is the so-called three-body problem and its extension, the *n* body problem, namely, having written out the equations of the motions of the sun, earth and moon, do these equations assure us of permanency except for slight self-correcting fluctuations? Eddington in his latest book comes to the conclusion that the universe is running down—that some day these planets and their satellites will revolve no more among that great galaxy of stars that God hath wrought. It is not a happy thought, even though we rejoice in the spirit and the joy of effort.

David Rittenhouse, living some twenty miles from Philadelphia, near the nineteenth milestone on the Reading Pike and four miles from what is now called Norristown, having already constructed clocks that surpassed in their accuracy those made in this country and abroad, conceived the brilliant idea of making a machine to simulate the motions of the planets, Mercury, Venus, Earth, Mars, Jupiter and Saturn, with their then known satellites. Comparing the tables then calculated and making many computations of his own he set up a machine which was so accurately devised that when you set the hands on the dials to any time five thousand years before or after 1770 you can with a small telescope make accurate observations of the places of these bodies in the heavens, just as if you had lived in that time long ago or long to be. Had there been an ancient Egyptian—even before the days of Ahmes the Moon Born, who wrote the "Explanation of All Dark Things," the earliest known mathematical book—who should wake up from some mummified body and remember that he had forgotten a priestly observation, he could rectify his laxity by turning these mimic orbs by means of a crank back till the hands pointed out the time, not to the nearest century or month but to the very day, hour and instant of his lapse. Then he could turn them forward and find out what horoscope



DAVID RITTENHOUSE

PROFILE OF BUST BY THE CELEBRATED CERACCHI WHILE IN AMERICA. NOTE THE EXPRESSION OF PAIN SEEN ONLY IN THIS VIEW OF THE HEAD.

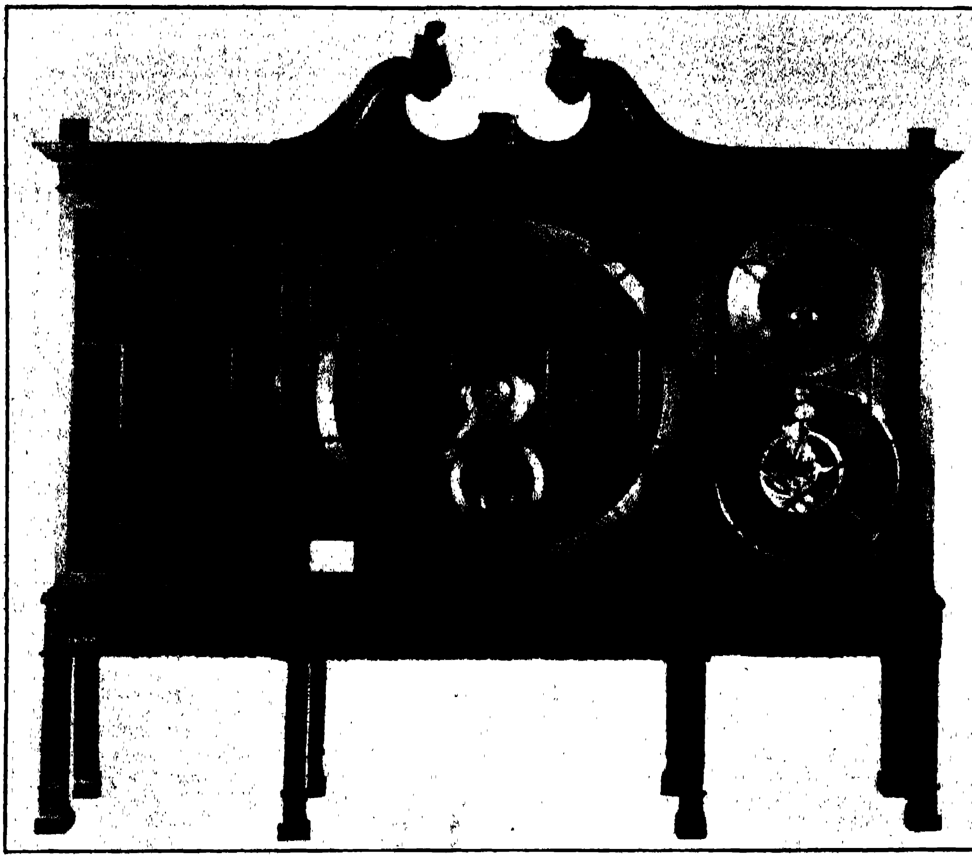
James Logan sent William Penn when the latter's son was born, and we could compare it with what we know of that young rascal who so foolishly sold the land that nourished David Rittenhouse. By it we could tell whether it was moonlight when Anthony walked with Cleopatra, or Abélard with Héloïse.

To the right of this central face is a lunarium, which will give the positions of the moon during the ten thousand years that this instrument is accurate.

It will tell the time, duration and character, whether total, partial or annular, of any eclipse of the sun or moon during that period and moreover will point out accurately the place upon the earth at which particular eclipses of the sun are visible. The Austrian mathematician and astronomer, Oppolzer, has made a table of all the eclipses during historical times; one of these stopped a great pitched battle between the Medes and Lydians on the 28th of May, 585 B. C. We can turn a crank and check all these eclipses and list all that are to come during the next five thousand years. This instrument is so in tune with the great handiwork of God that there is no doubt in the hearts of any of us that Eddington's awful prediction can not come within any time appreciable by us or ours. Men like Adams, Jefferson, Washington and others recognized the exquisite mechanics of Rittenhouse in making this image of the heavens above, though others professed to believe him an atheist, a mocker of God and a man of evil.

Let us use the Orrery, as it was called, in turning back over the life of Rittenhouse and his progenitors. We will find that, though we can reproduce the motions of the planets, the so-called fixed stars were beyond his ken and many of the comets were visitors from the unknown and that Rittenhouse has not even attempted to reproduce the motions of those captured by Great Jupiter. Though we can accurately trace the path of an eclipse upon the surface of the earth its hundred miles of breadth is here but a fine line, and there would be no glass powerful enough to pick out the people if they could repopulate the earth as they did in those long past days. As we turn the wheels of the Orrery, repeating again the position of the planets they saw, we will have to use the two eyes of history and tradition, each of which may tend to clear the vision and complement the view of the other. Let me illustrate: In that great first story of man and his creation, a woman came into the life of man, so biblical history tells us, though most of the beauty and grace of the tale has been lost in the torrential threats of hell and damnation that invariably accompanied its telling. But there is a tradition that down in the bottom of our hearts we firmly believe to be true. It is that that woman alone with that man, as no woman has been alone with any man since, feared repetition, and further tradition tells us that it was she who would first awake from sleep in the dawn of that creation and feverishly count the ribs of her mate in an ecstasy of fear and jealousy, and thus began that which we now call Arithmetic.

So I shall endeavor with the eyes of history and tradition to go back to the year 1644 when Isaac Newton was two years old, when England was still in the reign of Charles the First, having just begun to sense the reverberations of the Thirty Years War, that destroyed one in every three in Germany, and bled white the other two. In that year in England was born William Penn, the founder of Pennsylvania, and in Germany Willem Rüttinghüysen, papermaker of the Ruhr, who would set up the first papermill in Penn's green woods. In England the first born inherits the land and title, while the younger children take up the army or the priesthood or teaching or some other respectable but impoverished vocation. Admiral Penn, the young husband of a Dutch wife, saw that England would not cling to this king, yet thought still he could fight for England against her enemies without, until the family quarrel was settled. Though the first controversy with Charles was over ship money, England's navy took no part whatever in the civil war, so when sent to the West Indies on his own and his



THE RITTENHOUSE ORRERY

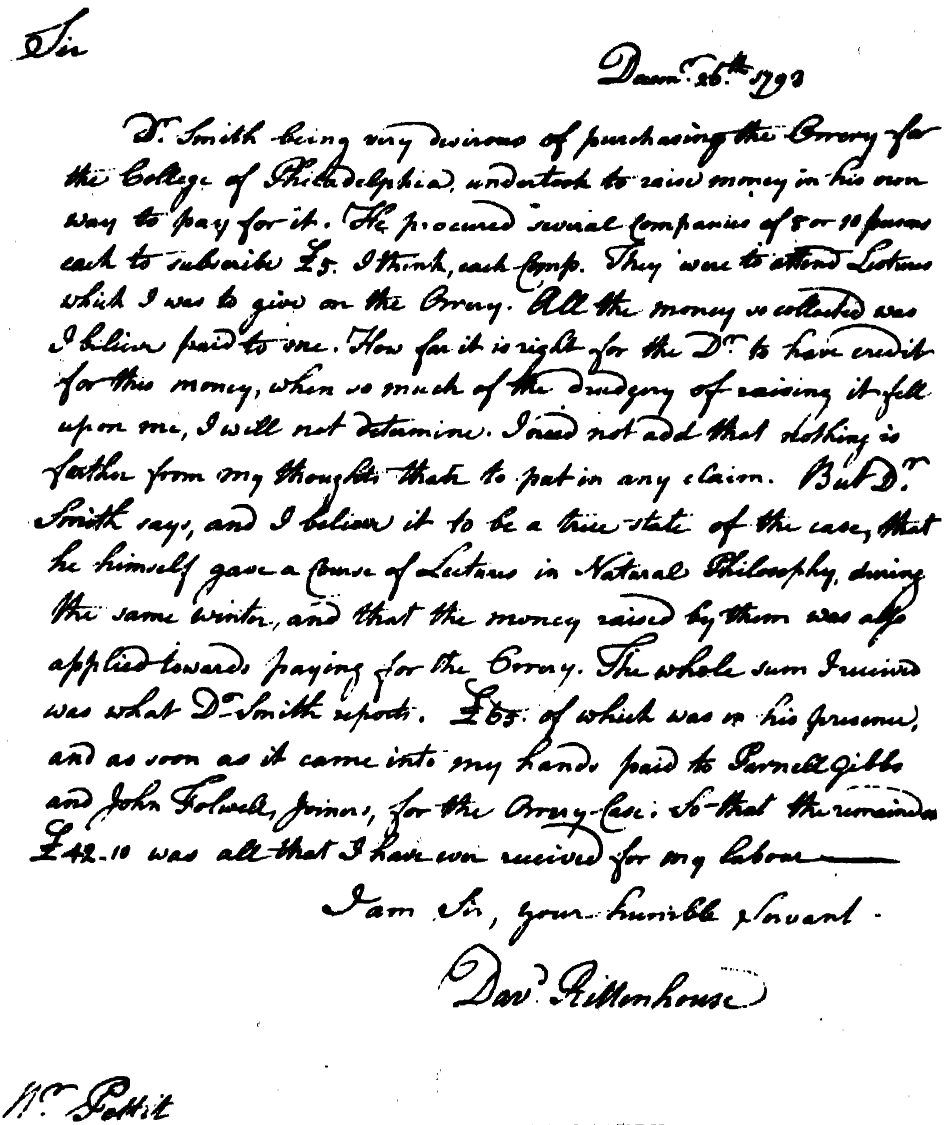
AT PRESENT LOANED BY THE UNIVERSITY OF PENNSYLVANIA TO THE FRANKLIN INSTITUTE, WHERE IT HAS BEEN BEAUTIFULLY RESTORED FOR USE WITH THEIR NEW ZEISS PLANETARIUM. THE CENTRAL FACE IS A PLANETARIUM; THE LONG ARM CONTAINS SATURN, HIS RING AND SATELLITES, THE SHORTER BRASS ARM JUPITER AND HIS SATELLITES, WHILE WITHIN ARE MARS, EARTH, VENUS AND MERCURY. THE LARGE CENTRAL BALL REPRESENTS THE SUN. THE SUN AND EARTH CAN BE REMOVED AND A SMALL TELESCOPE REPLACE THEM, WHICH WILL READ THE POSITIONS OF THE OTHER PLANETS THROUGH MARKINGS ON THE LARGE CIRCLE WHOSE INNER HALF MOVES AND REPRESENTS THE ECLIPTIC. THE HANDS FOR SETTING THE TIME 5000 YEARS BEFORE OR AFTER ARE IN SMALL CIRCLES BELOW. THE LUNARIUM IS ON THE RIGHT. THE DAYS OF FOUR CONSECUTIVE YEARS ARE ARRANGED IN A SPIRAL THREE DEEP. AND THE CENTURY YEAR, MONTHS AND DAY CAN BE VERY ACCURATELY SET IN THE UPPER PART. BELOW A CYLINDRICAL ARRANGEMENT IS DIVIDED IN 360 SQUARES REPRESENTING FIVE DEGREES OF NORTH AND SOUTH DECLINATION AND 360 DEGREES OF AZIMUTH. THE EARTH IS STATIONARY EXCEPT FOR DAILY ROTATION AND CHANGE OF AXIS, AND IS SITUATED IN THE SMALL CIRCLE AT THE VERY TOP OF THE LOWER FIGURE. A POINTER ATTACHED TO THE VERY COMPLICATED WHEEL WORK IN THE CENTER POINTS OUT ON THE INNER SURFACE OF THIS CYLINDER THE POSITION OF THE MOON. ITS DECLINATION AND RIGHT ASCENSION ARE EASILY READ BY THE OBSERVER LOOKING IN THE EYE-PIECE SHOWN NEAR THE CENTER OF THE WHEEL WORK. THIS HAS A 45 DEGREE MIRROR THROUGH WHICH THE POINTER IS CLEARLY VISIBLE AGAINST THE SILVERED SQUARES ABOVE AND BELOW THE ECLIPTIC. THE CIRCLE UNDER THE EARTH HAS AN HOUR HAND AND FRACTIONS OF HOURS ARE READILY READ. THE WHOLE CYLINDER MOVES SO AS TO KEEP THE EARTH IN ITS PROPER RELATIVE POSITION. OF

country's quarrel, after having fought with his wife's relations, the Dutch, Admiral Penn captured Jamaica. It is said that one of his captains reported to him on the Dutch possessions in America which the admiral ever afterwards looked upon as a means of restoring the younger branch of the Penn family to which he belonged. After the peaceful and spontaneous recall of Charles the Second the admiral sent Captain Holmes over again to take possession of the Dutch colonies on the eve of the last great war with Holland. And in due time, after some weeks in the same tower in which the Penns—father and son—dwelt more than once, Holmes' capture was acknowledged and the New Netherlands and the western bank of the Delaware became the property of the Duke of York, who had agreed to be guardian to young William Penn. The younger Penn cherished the tradition of his father toward this new land, yet having become a Quaker he yearned not for titles but only for a place to establish a green country town and to proclaim a land where all might be free and equal and undisturbed in their religious views. Passing over into Holland, doubtless realizing that the doctrine of "inner light" had been wafted across the Straits from the Rhine and being half Dutch himself he extended a gracious welcome to immigrants from the Lowlands. Francis Daniel Pastorius, a learned and emotional barrister, having just returned from "the grand tour" of Europe with a rich sprig of nobility, heartily answered the message and landed in America soon after the *Welcome*. In Philadelphia he built a little house above a cave and placed on it this inscription: *Parva domus, sed amica bonus procul este proephani*—Small is my house but open to good men and closed to the evil, at which Penn smiled and entered and invited him to dinner every day.

Pastorius, upon the coming of other chosen German Quakers, formed the weaver's village of Germantown, soon to be nicknamed because of its poverty Armentown. Here they lived as friendly Quakers until Pastorius and others brought before the various meetings their anti-slavery petition, saying they were against traffic in "men's bodies." Not receiving a quick and warm response they gradually grew cold to some of the Quaker customs and longed for a preacher of their own.

In Germany, where Willem Ruttinghuysen was born in 1644, it was the custom of the eldest son to remain under the parental roof until the second son became of sufficient age and strength to assist the father. The added earnings at this time enabled the father to set the oldest son up in business or on a farm or give him means to make a pilgrimage. This procedure went on until the youngest son was left to assist the declining years of his parents and finally take over the homestead and the family traditions. Thus it was that Willem Ruttinghuysen, the older son, left the family group at Mülheim and went down into Amsterdam in Holland to take up his trade of papermaker, which his family had somehow acquired from connections with the French Hugenots, for his watermark was also used by Wendelin Rehel of Strasburg and the crown and fleur-de-lis are from the arms of France. Soon after 1685 we

COURSE AN ECLIPSE ONLY OCCURS WHEN THE POINTER, WHICH REPRESENTS THE POSITION OF THE MOON, PASSES DIRECTLY IN FRONT OF THE EARTH, WHICH CAN ONLY HAPPEN WHEN THE POINTER IS NEAR THE ECLIPTIC WHEN IT PASSES THE EARTH AT THE 12 O'CLOCK POSITION. THE PHOTOGRAPH IS IN ECLIPSE POSITION WITH THE HOUR HAND DIRECTLY UNDER THE POINTER. THE LEFT FACE ORIGINALLY CONTAINED JUPITER AND SATURN AND THEIR ATTENDANTS. RITTENHOUSE REMOVED THEM WHEN HERSCHEL ANNOUNCED HIS DISCOVERIES AND NEVER REPLACED THEM.



Sir

Decem^r. 26^th. 1792

Dr. Smith being very desirous of purchasing the Orrery for the College of Philadelphia, undertook to raise money in his own way to pay for it. He procured several Companies of 8 or 10 persons each to subscribe £5. I think, each Comp. They were to attend Lectures which I was to give on the Orrery. All the money so collected was I believe paid to me. How far it is right for the Dr. to have credit for this money, when so much of the drudgery of raising it fell upon me, I will not determine. I need not add that nothing is farther from my thoughts than to put in any claim. But Dr. Smith says, and I believe it to be a true state of the case, that he himself gave a Course of Lectures in Natural Philosophy, during the same winter, and that the money raised by them was also applied towards paying for the Orrery. The whole sum I received was what Dr. Smith reports. £65. of which was in his presence, and as soon as it came into my hands paid to Parnell Gibbs and John Folwell, Joiners, for the Orrery-Case. So that the remainder £42.10 was all that I have ever received for my labour ——

I am Sir, your humble Servant.

Dav. Rittenhouse

Mr. Pettit

A LETTER ABOUT THE ORRERY

THIS LETTER WAS FOUND BY THE AUTHOR AMONG THE PAPERS RELATING TO THE CONFLICT BETWEEN THE OLD COLLEGE OF PHILADELPHIA AND THE NEW UNIVERSITY OF THE STATE OF PENNSYLVANIA BEFORE THEIR UNION. THE CASE OF THE ORRERY IS POSSIBLY OUR MOST MAGNIFICENT PIECE OF COLONIAL CABINET MAKING AND WOOD CARVING, AND ITS AUTHORSHIP WAS UNKNOWN BEFORE THIS LETTER WAS DISCOVERED.

find him setting out for America, possibly because of the influx of seventy thousand French Huguenots into the Rhine Valley and neighboring cities after the revocation of the Edict of Nantes or possibly from an adventurous longing to follow relatives who had settled in New Amsterdam as early as 1641, but most likely called as minister to complete the company of German-

town Mennonites. It is safe to say that he sailed on a Dutch vessel to New York, being warned by the baker Bom and other Crefelters of the poor fare and the danger of being let ashore on the lower Delaware, and other possible ill-treatment from English shipmasters. There likely was a lack of English shipping because of the rebellion leading to the accession of William and Mary. Tradition tells us that he arrived in Pennsylvania with his sons Garet and Claes or Nicholas and his daughter Elizabeth in 1688, and that there was a courtship on the boat, for we find that the bans were read on the 10th day of May and that a marriage takes place in the Dutch Reformed Church in New Amsterdam on the 29th of May, 1689, between this younger son, Claes, late of Arnheim but now of the Lower Delaware, and Willjmintie Dewees of Lieuwardn and now of New Netherlands. Claes brings his bride and her brother William through Jersey, crossing the Delaware near the Falls and passing down near Penn's country seat to join her parents, Garett Hendricks and Zythian, descendants of Jan Pietre (De wees—the orphan), and other members of this family, possibly all originally from Mülheim and former neighbors of the Rittenhouses. This year they seem to have spent in building some sort of habitation in the wild and beautiful but closed glen of the Wissahickon (this valley was closed in by an immense group of rocks at the Ridge Road until 1826).

In 1790 as members of a company formed by Samuel Carpenter, who held the land, William Bradford, the Caxton of America, Robert Turner, old friend of Penn, and Thomas Tress, they erected the first papermill in America on a small branch of the Wissahickon. This labor was accomplished entirely by their own hands without the aid even of barrows, there being no connection with the outside world, except bridle paths to Germantown and boats to Philadelphia. The wheel they first erected was undershot and connected by wooden cogwheel work to the wooden trip hammers that beat up the pulp and smoothed the sized paper obtained from the man-carried waste product of the weavers in Germantown and what rags could be gathered in the city. Richard Frame writes thus in "A Short Description of Pennsilvania or a Relation of What things are Known, Enjoyed and Like to be Discovered in the said Province":

> The German-Town of which I spoke before
> Which is, at least in length one mile or more,
> Where lives High German Peple and Low Dutch,
> Whose trade in weaving linen Cloth is much,
> There grows the flax, as also you may know,
> That from the same they do divide the Tow;
> Their trade fits well within this habitation,
> We find convenience for their Occasion,
> One trade brings in imployment for another,
> So that we may suppose each trade a brother;
> From linen rags good paper doth derive,
> The first trade keeps the second trade alive;
> Without the first the second cannot be,
> Therefore since these two can so well agree,
> Convenience doth appear to place them nigh,
> One in Germantown, t'other hard by.
> A paper mill near German-Town doth stand,
> So that the flax which first springs from the land,
> First flax, then yarn, and then they must begin,
> To weave the same which they took pains to spin.
> Also when on our backs it is well worn,
> Some of the same remains ragged and Torn;
> Then of the Rags our Paper it is made;
> Which in process of time doth waste and fade:
> So what comes from the earth, appeareth plain,
> The same in Time, returneth to earth again.

Under the caption "Save Your Rags" the following advertisement appeared at a later date in New York:

> If the necessary stock is denied paper mills young maids must languish in vain for tender epistles from their respective swains. Bachelors may be reduced to the necessity of personal attendance on the fair.

The paper molds, probably about twenty by thirty inches, were made of

fine screens of reed on the inside of which were placed wires bent in the form designed for a watermark. These molds were dipped into the vat of prepared and beaten pulp which by a quick motion of the hands was spread over the inside surface of the mold. The water from the pulp running through the screen, and the sheet losing much of its moisture, took on the shape of a very wet sheet of paper, the design of the wires laid in the mold caused by their unevenness the watermark. When the skilled papermaker thought the sheet to be sufficiently dry, he turned it out on a kind of blotter which he had placed on the preceding sheet.

In this mill worked at papermaking the older Willem, his two sons and William Dewees, though Garett seems to have soon left and gone to Germantownship. William Dewees in 1710 founded the second paper mill in America, which was in 1713 bought out together with one hundred acres of land by his brother-in-law, Nicholas, William Streepers and John Gorgas, for one hundred and forty-five pounds. The women of the family were kept extremely busy picking and sorting the rags and with other duties about the mill. Willem, the elder, the preacher of the Mennonites in Germantown, became their first bishop. In 1702 a tremendous flood washed away the mill, with all its tools and belongings. William Penn contributed twenty-five pounds and called the elder Willem "old and decrepid," though he was only fifty-eight, the same age as Penn himself. Hard labor and long hours used to make men give up at fifty and sit in a chimney corner for the balance of their lives. The mill was rebuilt and came into the hands of the Rittenhouses alone, who seem to have been prosperous. From June, 1709, to April, 1710, Bradford purchased paper amounting to thirty-six pounds, 13s, 3d. Nicholas made press, writing and brown paper. Here were born the sons of Nicholas and Wilhelmina, William, Henry and Mathias, the latter in 1703, and their daughters, Psyche, Catharine, Mary and Susanna. In 1708 Willem the elder died and was buried in the lot of the old Mennonite meeting house in Germantown; and Nicholas carried on the mill, preached on Sunday and did pastoral work as had his father. The children went to school to Daniel Francis Pastorius at Germantown, whose experience in Philadelphia in whipping the boy Israel Pemberton, later the great Quaker merchant, proved how disastrous it was to cross this famous trader. Finally, after the second William had moved to a farm nearby and his brother Henry to a farm in Worcester Township, Mathias, having remained with his father, took to himself in 1727, the year of Newton's death, a wife, Elizabeth Williams. William Barton, Rittenhouse's nephew, says, "She was a daughter of Evan and Dorothy Williams, Welsh Quakers." Of them I find no record, but it is interesting to note that Susanna, the daughter of the wealthy Jacob Telner, who married Albertus Brant, after his decease married a second husband, one David Williams, about the year 1700. As the name Susanna appears frequently in the Rittenhouse family and Mathias Rittenhouse's wife's brother is named David Williams, there is room for thought. However this may be, Elizabeth Williams seems to have been a woman of "uncommon mind" but with an education "having been much neglected in her youth as is common with orphan children." She seems to have been afraid for the health of her family in the dark valley and at the papermaker's trade and interests her brother-in-law, Henry; they influence Mathias to make a purchase of land from the Norris family, who owned the

manor of Willem Stadt, which Penn had given to his son William and the latter scapegrace had sold almost immediately for pocket money and back debts. It was this Isaac Norris who purchased in London in 1705 for James Logan, Hays fluxions, of which there are two copies in the Loganian Library. In his spare time Mathias seems to have added to the stone house previously built at Norriton, but stayed according to tradition with his father in the new house with the coffin door, and no steps therefrom, that still stands in the park on Lincoln Drive, the only one preserved of the four residences of David Rittenhouse. Here a daughter Esther and a son David, the latter born April 8, 1732, old style, were added to the little family. Eventually in 1734 Nicholas died, and by brotherly agreement the oldest son William took hold of the mill, while the younger family moved to the farm at Norriton, Elizabeth's two younger brothers going with them. At the corner of the farm they found an old Presbyterian Church which had probably been Dutch Reformed in earlier days and whose claim was from "the time whence the mind of man runneth not to the contrary." So to the "said Presbyterian profession" in consideration of "one silver half crown current money of England to them in hand paid," they gave a deed. A few years after they had moved came the great earthquake of December 7, 1737, felt for three hundred miles. It sounded to little David like a great multitude running to and fro in the loft overhead. On September 14, 1735, a warning appeared in the *York County, Virginia, Record:* "It is ordered that it be a standing rule of this court that the Sheriff doth not summon any person to be of the grand jury, who he shall know to be a Drunkard, a common swearer, a Sabbath breaker or Surveyor of the highway, or guilty of any other misdemeanor." Thus, here under the tuition and care of his elder sister Esther, David Rittenhouse began his acquaintance with life, probably going to school in the Presbyterian Church, afterwards and between times taught by his Uncle David, after whom he was named and who had learned the carpenter's trade and been interested in mathematics and possessed a translation of the first book of Newton's Principia. This young man was "delicate" and much at home, so we can imagine with what eagerness the young David listened to the older David about the mystery of mathematics and the use of tools. On bad days they crept up one of the four winding stairs into the great garret and there pored over mathematics and read and reread Poor Richard's Almanac and the *Pennsylvania Gazette,* and talked as boys can and do of their hopes and plans for the future. Young David must have been disappointed when they read in Poor Richard's Almanac when he was six years old the following: "You will excuse me dear reader that I afford you no eclipses of the moon this year. The truth is I do not find they do you any good. When there is one you are apt in observing it to expose yourself too much and too long in the night air whereby great numbers of you catch cold, which was the case last year to my very great concern. However, if you will promise to take more care of yourselves you shall have a fine one to stare at the year after next." In 1743, when David was eleven, he was allowed to stay up late and he and his uncle saw a total eclipse of the moon on October 1st at 10 o'clock in the evening. There was also a figure in Poor Richard's Almanac illustrating the cause of eclipses.

These were stirring times in 1742. Gentle Mathias came home much beaten up from the great election. The great Whitfield had been preaching virtually to thousands. In Philadelphia a build-

ing was erected in 1740 for him to preach in, and Samuel Pennypacker claims this was the beginning of the Academy, afterwards the College of Philadelphia and now the University of Pennsylvania. This was the time when the governor's council denied the right of assembly to appoint other doctors in the place of Dr. Graeme, port physician. The government was in the king and his appointed representatives and was never dissolved. Assumption by the assembly of executive power was a "bare-faced Republican notion."

At Norriton, Hell Fire John Rowland was in charge but was getting, like Cuthbertson, "tired of the ungodly." This was the beginning of the "new lights," the germ of the "rabid whigs," who controlled Philadelphia politics until 1789.

Poor Richard's Almanac of 1744 gives rising and setting of planets "so those who are disposed can learn to distinguish one from the other." That of 1747 promises two total eclipses of the moon, midnight, Feb. 13, and 9 P. M., Aug. 9. In 1748 the Copernican and Ptolemaic systems are explained. Poor Richard compares Ptolemy to a "whimsical cook, who, instead of turning his meat in roasting, should fix that and contrive to have his whole kitchen fire and all whirling continually round it." Mentions Newton's death in 1727 and quotes, "Nature and nature's laws lay hid in night. God said, Let Newton live and all was light."

When David was only twelve years of age Uncle David died and left him his tools and books and he had to carry on the double dreams of the two boys. I would like to give you some of the atmosphere of the times, how they told this sad news to four neighbors and how in the same way it traveled over the countryside, bringing the whole neighborhood to the funeral, how they always knew when neighbor James's sick daughter was going to meeting because her father was out early in the morning smoothing up the long lane with a hoe and rake so she would receive no jar on the journey, how at meeting when the question was put "Has anyone anything to say?" that Lydie Tucker rose and said, "Lewis promised to marry me," but as nobody else said anything the wedding went on. How Aunt Emmy used to sew feverishly when her thread was short, to get through before it ran out. How the weather then was just as peculiar as it is now, though the German historian Ebling says "the dews were often heavy enough to start a dry stream." How after the Quakers withdrew from politics, Philadelphia became strangely neglectful of her own nestlings, seemingly ashamed of even her legitimate children if they began to attract public notice in Philadelphia before becoming known in foreign parts. This incidentally was the time of the young pretender in England. Many things can be told of our simple Germans and Quakers and fiery Scotch-Irish Presbyterians that would lead you to a better understanding, but I must go on and tell about David. This is the time that we find the handles of his plow and the fences marked with soapstone where he had paused at the end of a wavering furrow to rest his horse and work out some problem that had begun to trouble him far across the field. In after years his younger brother Benjamin was prone to tell of this figuring with pride in a budding genius, though his previous telling may have been taken as evidence of times of idleness, for it was said David rested old Dobbin overlong at the end of the furrow.

Coming home from the old papermill our hero made a waterwheel and then a clock, a wooden one with three wheels, but not content with this he soon made others, using brass for the works. In this he was encouraged by articles in Poor Richard's Almanac upon the regu-

lation of clocks. So he and his mother finally persuaded father Mathias to buy sufficient tools and materials to set him up in a shop by the side of a road.

His every clock was different and better than the last, for he studied and improved his mind. Some days when he had finished a task and needed a new one he would walk the twelve miles to the school of Patrick Menan at Marble Hall, where every student was in a class by himself, more especially David. Men in America had learned to walk from the Indians. David was only five years old when the Indians first felt themselves cheated by the Walking Purchase, and he had early walked to Shipback and Salford, where Christopher Dock, the first American writer on school management, taught on alternate days. A man could and often did outwalk a horse in those early trackless days. And walking is good for thinking.

In 1751, when David was nineteen, Thomas Barton, a graduate of Dublin University, came to teach school at Norriton and opened up a new world of learning. They started a lending library so as to pass on the good things to others, and the next year Barton became a tutor in the academy, which soon became the College of Philadelphia, to which had come the able, energetic and discerning Rev. William Smith. In 1753 Barton married, at Old Swedes, David's favorite older sister, Esther. About a year after this Barton sailed for Europe to obtain orders as a rector of the church of England and returning brought many scientific books to add to what David was obtaining from the college and the library of James Logan. So filled were David's days and nights in attempting to keep up with this torrent of learning that he had a breakdown, and sensibly stopped all work and took the baths at Sulphur, now Chester Springs, and later those near his brother-in-law's farm at one of his charges in what was then York County. Recovering from this illness he was ever afterwards plagued, as he described to his nephew, William Barton, "with a constant heat in the pit of the stomach; affecting a space not exceeding the size of half a guinea attended at times with much pain," and which disturbed him greatly in the position of writing.

In 1756 he made an eight-day clock for Thomas Barton, which had on the upper dial plate "Tempus Fuget" and beneath "Mind your business." This clock was lost in New York or carried to England. In the year 1758 Barton was chaplain to one of the king's American regiments. He says that he rode out to meet Colonel Washington coming with troops from Fort Cumberland, and finding Washington on foot dismounted and walked back with him seven miles. He tells afterwards of the perils with the Indians and of his preaching for Washington on Nehemiah 4:14. It was through Barton that Rittenhouse became acquainted with Washington, for whom he made a surveyor's compass, and much later spectacles and a reading-glass. In 1763 Rittenhouse and Provost William Smith were making surveys to connect Lake Erie by water with the Delaware, before any canal was built in England, and thus prevent the loss of the lucrative Western trade to New York and Baltimore. Ever since the first granting of Penn's charter there had been a dispute between Penn and Baltimore. Cresap said that "Philadelphia was the damndest, prettiest city in Maryland," and Penn's claim would have taken in even the present Baltimore City and given him a port on Chesapeake Bay, probably Oxford, Robert Morris' old home. The charter granted land to Penn from the beginning of the fortieth to the beginning of the forty-third parallel of latitude. When all the previous charters had been granted, a degree of latitude was thought to be only sixty English miles. J. Picard

of France announced in 1671 that the length of a degree of latitude was nearly seventy common miles. There is a question as to whether Newton knew accurately the size of the earth or whether he was held up that twenty years because he did not know how a sphere attracts an outside particle, as Adams and Glaisher claim. The preponderance of opinion apparently favors the old explanation, as voiced by Noyes in his "Watchers of the Sky":

> . . . Newton withheld his hope
> Until that day when light was brought from France,
> . . . To the throng,
> Those few corrected ciphers, his results,
> Were less than nothing; yet they changed the world.
> For Newton seized them and, with trembling hands,
> Began to work his problem out anew.
> Then, then, as on the page those figures turned
> To hieroglyphs of heaven, and he beheld
> The moving moon, with awful cadences
> Falling into the path of his law ordained,
> Even to the foot and second, his hand shook
> And dropped the pencil. "Work it out for me,"
> He cried to those around him; for the weight
> Of that celestial music overwhelmed him;

You will also see what a trouble and mess this made out of the old grants to have a degree nearly ten miles longer than it previously had been. The claims of Maryland were thought to have been settled by the Chancery Court decree issued in the year of Rittenhouse's birth, but the dispute still hung on and in 1763–64 Rittenhouse was employed by the Penns, through the Reverend Richard Peters, then their secretary, to make intricate calculations and to fix certain points of the twelve-mile circle about New Castle, for which he says he was handsomely paid. We know that in 1767 Mason and Dixon, after a short stay at the Plumstead house, No. 30 South St., designated as the most southerly point of Philadelphia, loaded their instruments in a wagon and went directly to what is now called Harlan's Corner, near the Chester County Poor Farm and spent the winter there, and that there remains in the shifting sands of a field above the house the so-called Star Gazer's Stone. Immediately south of the house was their observatory, from which they measured a south line crossing the Brandywine three times in the first mile. They continued this and on a part of it measured out a degree of latitude. This line is over four miles east of the eastern boundary of Maryland. They probably didn't want to make any of their preliminary calculations on Lord Baltimore's territory. Finally, they measured fifteen miles south from the then position of the stone which was in the latitude of the most southerly part of Philadelphia. From this point they proceeded to locate the northeastern corner of Maryland and to lay out Mason and Dixon's line. The method was to start off from each station on the arc of a great circle, just as steamers do to-day, then at intervals they checked back south on the meridian to the latitude of their starting point. In this manner they continued until stopped by Indians.

Pennsylvania had been settled first by the English, who carried on the peaceful tradition of the Swedes and Dutch. Next came a great shock-absorber belt of Germans and on the outposts the Scotch-Irish, who without let or hindrance felt that no Christian should be without land while the savages had so much. In 1763 both Barton and Rittenhouse were much incensed at the so-called Paxton riots. Some friendly Indians who had sought the protection of the government were interned in the barracks and prison at Lancaster. They were set upon by the Paxton boys and all killed; the last one, a little boy who had been clinging to the rafters of an outhouse, was dragged down by an old greybeard and held by one hand while

his brains were blown out by the rifle held in the other. Immediately the old preacher dropped on his knees in the blood of the boy and praised God for the deliverance. Excited by their success, the Paxton boys marched on Philadelphia to destroy the Indians there, but were delayed in Germantown and persuaded to return. On the other hand, the Reverend John Ewing, first provost of the University of the State of Pennsylvania, gives us a much lighter story of the Paxtons and blames the Indians, much as did Jonathan Edwards in New England. In 1765 Samuel Purviance wrote Colonel James Burd "to let it be spread abroad through the country, that your party intend to come well armed to the election—and that you will thrash the Sheriff, every inspector, Quaker and Menonist to jelly," but all was in vain as yet.

In February, 1766, at Norriton, the Reverend Thomas Barton united David Rittenhouse and Eleanor Coulston, the daughter of a neighboring farmer, in marriage, he having assumed the family estate by taking upon himself certain obligations generally belonging to the younger son. Here on the 23rd of January, 1767, was born his oldest daughter, Elizabeth, named after his mother, and later, 1788, the wife of Jonathan Dickinson Sergent, and on December 1, 1768, a second daughter Esther, named after his favorite sister, and in 1789 the wife of Dr. Nicholas B. Waters. On November 17, 1767, the College of Philadelphia had bestowed upon him the degree of Master of Arts, "being well assured of the extraordinary progress you have made by a felicity of natural genius in mechanics, mathematics, astronomy, and other liberal arts and sciences, all of which you have adorned by a singular modesty and irreproachable morals." This same year he commenced the observatory at Norriton, made a mettaline thermometer and investigated the compressibility of water.

The year 1769 was an extremely busy one. Not only did he settle the boundary between New York and New Jersey, but he was busy making all the instruments for observing at Norriton the transit of Venus, which occurred on June 3rd of that year. The legislature had appropriated one hundred pounds, and the newly organized American Philosophical Society had appointed a committee which was to meet at State House Yard, Norriton and Cape Henlopen. The public contributions and the public money were principally at the disposal of the State House committee, where a small wooden platform was erected for the observations of the subcommittee headed by Dr. John Ewing. This observatory was the stand from which was first read the Declaration of Independence.

It was owing to the patience, skill, labor and public interest of Rittenhouse that the Norriton observatory became the chief part of the enterprise. Here Dr. Smith used a reflecting telescope sent by the Penns through Dr. Rush and later to be the property of the college. There was also an astronomical quadrant of 2½ foot radius made by Sisson. This instrument was similar to the smaller one made by Rittenhouse and afterwards used by Andrew Ellicott, surveyor general of the United States, now preserved in the Smithsonian Institution. Rittenhouse used this quadrant for obtaining the latitude of the observatory at Norriton and it was returned to New Jersey, where we trust it has been preserved. Rittenhouse also made an equal altitude instrument, a transit telescope and of course a most excellent clock. All these are now the property of the American Philosophical Society and the University of Pennsylvania. The calculations from the Nor-

riton and Greenwich observations, as given in the Appendix of the Astronomical Section of the First Volume of the transactions of the American Philosophical Society, gave the sun's horizontal parallax as 8.805″. You may read both the American and European correspondence in this same volume.

The transits 1739 and 1761 had been unlucky. Reverend Horrox, who calculated the one of 1639 the first observed, had to attend service while it was in progress. The British everywhere met clouds or were prevented by the French. Mason and Dixon were chased home by the French and reluctantly sailed a second time. All Maskelyn had to show for a visit to the West Indies was a seven hundred dollar liquor bill and a new method for obtaining longitude. The Leipzig observer who had gone far enough north to prevent the sun setting in the midst of things was accused of falsifying his records, but many years afterwards the eminent American astronomer, Simon Newcomb, proved that the accuser was both color blind and mistaken. One Frenchman, Le Gentil, prevented by the English from landing, stayed eight years longer in the East Indies till 1769 and found it cloudy and so came home, for he wouldn't have a chance again until December, 1874. Rittenhouse also observed the transit of Mercury, November 9, 1769.

At this same time Rittenhouse was working on his orrery, a name gotten from the fact that the Earl of Orrery unwittingly patronized a planetarium whose plan was stolen by one Rowley from its inventor, George Graham. The King of England paid Rowley a thousand guineas, though the instrument only contained the sun, earth and moon. The financing of the Rittenhouse machine is the first instance of a research fund in America. Barton wrote to Rittenhouse:

> I would have you pursue your Orrery in your own way without any regard to an ignorant or prevailing taste, all you have to study is truth and to display the glorious system of Copernicus in a proper manner and to make your machine as much an original as possible. I beg you will not limit yourself in the price. P.S. I beg leave to recommend Huyguns, Cotes, Horshams, and Powers philosophy to you. I wish you would purchase Bion's description of Philosophical and Mathematical instruments.

Dr. Witherspoon, president of Nassau Hall, now Princeton, rode out to Norriton and paid Rittenhouse three hundred pounds for his orrery, to be finished later. It was a source of great pride and of many appropriations to the college until it was lost some time after its return from the Chicago World's Fair of 1893. The second orrery, finished nearly as soon as the first because of the need of importing brass from England, cost the University of Pennsylvania nothing. Rittenhouse received forty-two pounds and ten shillings after a great deal of labor by him, and Smith, Parnell Gibbs and John Folwell were paid sixty-five pounds for making its magnificent case. The always generous legislature of that day awarded David Rittenhouse three hundred pounds as an appreciation of his genius. The "Vision of Columbus" alludes to it as follows:

> See the sage Rittenhouse, with ardent eye,
> Lift the long tube and pierce the starry sky;
> Clear in his view the circling systems roll,
> And broader splendours gild the central pole.
> He marks what laws th' eccentric wand'rers bind,
> Copies Creation in his forming mind,
> And bids, beneath his hand, in semblance rise,
> With mimic orbs, the labours of the skies.
> There wond'ring crowds with raptur'd eye behold
> The spangled Heav'ns their mystic maze unfold,
> While each glad sage his splendid Hall shall grace,
> With all the spheres that cleave th' ethereal space.

Rittenhouse came to Philadelphia expecting to be appointed to a position in

the Land Office at two hundred pounds a year, but owing to a sudden adjournment of the legislature this did not happen. Very soon after arriving in the city his young wife died, and the visit of a comet was only a momentary comfort, even though he caught Winthrop of Boston in an error.

Early in 1771 he was elected one of the secretaries of the American Philosophical Society, and in the latter part of the year, at the instigation of Richard Peters, he was elected to take charge of the orrery and to give occasional lectures at the college. He also took the position of caring for the State House clock. The years 1771 and 1772 find him of a mind to go to England and exhibit his orrery. His state of mind is such that his little niece, Hetty Barton, whose commonplace book is preserved at the university, accuses him of being in love and we find him marrying Hannah Jacobs on the very last day of 1772. In 1773 he was appointed a commissioner to make the Schuylkill navigable, and in 1774 to settle the boundary between New York and Pennsylvania. He and Captain Holland, of the British Army, established the northeast corner of Pennsylvania, but because of the intense cold did no more until 1787. In May, 1775, the American Philosophical Society petitioned the legislature to establish a Colonial observatory and appoint Rittenhouse the director, because he could not only direct the observations but he could make all the instruments, but Lexington and Concord had been fought. Nobody has ever satisfactorily explained the coming of the revolution. John Adams said that the crisis had occurred ten years before. Somehow, before England or America realized it, the revolution was on. Charles Thomson felt that had the Whigs in the legislature been let alone they would have united the whole Province, rich and poor, for the old families highly valued their long-held seats in the legislature. So Franklin and Rittenhouse, being the only men known throughout the state, were brought into the conflict to give it the authority of their partisanship. Franklin and Rittenhouse were appointed on the committee of safety, of which Franklin was chairman and Rittenhouse the engineer. Rittenhouse was on the Council of Safety, of which he was vice-president, and the Board of War of the Supreme Executive Council. He was one of twenty-four men having the power of life and death. We find him making a survey of the River Delaware and the surrounding country for fortifications and laying out the forts which resisting, after Washington's defeat at the battle of Brandywine, would have made the British position untenable had the decision of Germantown been in favor of the Americans. Finally, they were destroyed after great loss. He made and rifled cannon. Joseph Galloway said before the English Parliament that the American artillery depot was at Norriton in 1776. Also we find him designing with his friend, Owen Biddle, iron clock weights to exchange for lead ones. Charles Wilson Peale and he almost put their eyes out experimenting with telescopic sights on rifles. They might have been much more hurt if Peale's cartridge box had not fallen open and lost him his ammunition on the way to the proving grounds.

Rittenhouse was elected to Franklin's seat in the legislafure and afterwards to the Constitutional Convention, where after a few days' preliminary skirmishing he was made chairman of the committee of the whole, so that he or Franklin then presided at every session. Cannon, Rittenhouse and Jacobs, his brother-in-law, were appointed to write the preamble and oath. The committee was loaded against Cannon and from the

Roberts collection at Haverford College there is very great evidence that he was more of a talker than a writer or doer, even though he is known as the author of the letters of Cassandra. Franklin and Rittenhouse and Vanhorn were on the committee to recast the wording. Much has been said for and against this constitution. When examined closely it is a Unicameral constitution along the lines of the British instrument and does not have the conservative checks and balances of the constitution of 1789 which was made to conform to the similar one of the constitution of the United States. Some of the different features were a prohibition against continuous office-holding, which must have been objectionable to McLean, whose double office-holding in two states so excited an old German that he would not vote for a bill establishing a life insurance company, saying "if we do this old McLean will get insured and he'll never die and he'll hold office forever." Also there was a board of censors elected every seven years to criticize the constitution, its manner of administration and to advise changes in method and to make amendments. There was early opposition, but it was smothered. Soon after this Rittenhouse was elected state treasurer and the constitution allowed him to accept no other office.

I will not speak of the terrible winter of Valley Forge, when Provost Smith lived near Valley Forge on the Island of Barbadoes, opposite what is now Norristown and which was later proposed as the site for the university. When Mrs. Rittenhouse and her daughters dwelt at Norriton, David stayed with William Henry at Lancaster and even General Mifflin joined the "Conway Cabal" till Cadwallader closed Conway's lying mouth with a bullet. As soon as the British left Philadelphia Rittenhouse drove from Lancaster to Philadelphia with his instruments and a load of household goods and within a week was engaged with Smith and Biddle in making the first really scientific observations in America of an eclipse of the sun. These observations are preserved in the handwriting of Provost Smith.

Thomas Jefferson wrote to him July 19, 1778, "I sincerely congratulate you on the recovery of Philadelphia," inquired after the orrery and Rittenhouse's papers, and then went on to say, "though I have been aware of the authority our cause would acquire with the world from its being known that yourself and Dr. Franklin were zealous friends to it and am myself duly impressed with the sense of the arduousness of government and the obligations those are under who are able to conduct it; yet I am also satisfied there is an order of geniuses above that obligation and therefor exempted from it. Nobody can conceive that nature ever intended to throw away a Newton upon the occupations of a crown. . . . I doubt not there are in your country many persons equal to the task of conducting government: but you should consider that the world has but one Rittenhouse, and that it never had one before. The amazing mechanical representation of the solar system which you conceived and executed has never been surpassed by any but the work of which it is a copy."

Parson Odell wrote in 1779 in the *Royal Gazette:*

There dwelt in Norriton's sequestered bowers,
A mortal blessed with mathematic powers,—
To whom was David Rittenhouse unknown?
Fair Science saw and marked him for her own.
His eye creation to its bounds would trace,
His mind the regions of unbounded space.
While thus he soared above the starry spheres,
The word of Congress sounded in his ears;
He listened to the voice with strange delight
And swift descended from his dazzling height.

Soon after this in 1779 the legislature, in spite of a clause written by Dr. Smith

and put in by Franklin to prevent this very thing, dispossessed the college and erected the university of the State of Pennsylvania to carry out its projects and use its resources and those of sequestered estates. Smith went to Chestertown, Maryland, and established Washington College. Rittenhouse was appointed, because of his political position, trustee of the new university, but was in 1779 elected professor of astronomy and later in 1780 vice-president and could no longer be trustee. At the time that Smith temporarily gave up the fight in '82, Rittenhouse resigned his professorship and was immediately elected trustee and soon thereafter, through the enterprise of Francis Hopkinson, the orrery seal was adopted as a compliment to the great scientist. Finally, in 1789, after nearly thirteen years of service, Rittenhouse resigned as state treasurer, having been defeated at the polls as a candidate with Franklin for the old constitution. He had had some respite from the fatigues of this office in finishing the southern boundary of Pennsylvania and the western boundary to the Ohio and later the eastern part of the northern boundary, which he ran through a dense wilderness, by getting the latitude of points on a random line with zenith sectors of his own making and correcting back on the meridian. Rittenhouse and Ewing also ran the boundary between New York and Massachusetts at the request of Congress. During these journeys, in spite of the fatigue and great exposure, he was in much better health and was joyous and popular with his associates. The visits of great men in that day as in this excited the emulation of those less scholarly. On June 1, 1785, on Mason and Dixon's line while awaiting the arrival of Rittenhouse, Andrew Ellicott tells of the talents of Major Brownfield, who rode up to the meeting place of the commissioners and shouted "Hoollo, the host, the host, take my laborious dumb animal and put him in a separate department by himself, and give him proper nutrils such as a dumb animal may consist on and I will abscond for it in the morning." Ellicott often speaks of the wide vista they can see, reaching back ten, fifteen and from a high elevation even forty miles, the hundred-feet-wide clearing looking like a thread in the distance. He describes their way of living, saying they "arise in the morning about six or seven, they observed the sun's altitude between seven and ten, dined between twelve and one, after which we always drink our two bottles before leaving the table, then observe the sun's corresponding altitude, at six we have a large bowl of wine syllabubb. This rule we never break—we have each of us a cow. We drink our tea about seven and sometimes observe the heaven's the greatest part of the night." In December, 1785, he paid a long visit to Rittenhouse and they went together to talk with Benjamin Franklin. Again in the next April he arrived in Philadelphia on the 19th, visited with the New York Commissioners on the 20th, 21st and 22nd and is delighted with Miss Hetty Rittenhouse's vocal music. On the 23rd of April, still being at the Rittenhouse's he enters the following in his diary:

> April 23rd—Not only being Sunday but likewise the birthday of my friend Mr. Rittenhouse—he was born April 23rd, 1732, and one of those instances where strength of genius independent of a liberal education or even the common advantages has raised himself a monument of fame more durable than all the glittering pomp attendant on wealth and power—without tutors and almost without the aid of books he mastered the most critical and sublime parts of science and is now justly esteemed the first astronomer in this new world and perhaps inferior to none in the old—his life is as remarkable as his genius with a modest diffidence ever attending merit added to his most prudential conduct has secured his fame without creating one enemy or exciting envy.

Spent great part of this day at William Barton, Esquire. He is a most judicious gentleman and valuable citizen—and was presented by himself with some of his political writing.

He was a fellow of the American Society of Arts and Letters, 1782; a member of the Virginia Society of Arts and Sciences, 1785; a foreign member of the Royal Society of London, in 1795. In 1790 he succeeded Franklin as president of the American Philosophical Society. Three times he received the honorary degree of master of arts; from the University of Pennsylvania 1767, William and Mary 1784, Princeton 1782, and doctor of laws from Princeton 1789. He was connected with the College and University of Philadelphia, the University of the State of Pennsylvania, and the University of Pennsylvania from 1771 to 1796, until 1779 as lecturer and in charge of the philosophical apparatus, for a brief period trustee and then until 1782 professor of astronomy and vice provost of the university, and trustee thereafter. It was Rittenhouse, unless Fantana preceded him, who first used spider threads for cross-hairs in his telescope, besides inventing the collimating telescope in 1785. It is interesting to note that though engaged in arduous public work he published on the average one paper every year from 1780 to 1796, many highly original and over a wide field—on optics, Fraunhofer gratings[1]; optical illusions, modern psychology; magnetism, Ewing's principle; electricity, fourteen experiments with Kinnersley; logarithms, model and expert computation. One was read on March 3, 1780. The instrument maker, Short of London, found, when using his Cassegrain telescope alongside a reflector, that the mountains of the moon became valleys and *vice versa* and he discarded the instrument. Rittenhouse looked through a telescope at a brick pavement in his fireplace. The bricks looked sunken and the joints raised. At first he thought it was a necessary complement to the inverting of the image, but being a scientist he had to be certain, so he took out the lenses to find the same illusion. He shut off all but one window with no effect. Then he used a mirror in the fireplace, upon which alone a ray of sunlight fell. This caused things to look natural and he repeatedly alternated this effect. Then he put his finger on the bricks and the trouble at the same time, and his mind, realizing his own flesh and blood, corrected the illusion and after a few trials was fooled no more. What a lesson in morals. We need something to hold on to and after we have held on several times we can go alone.

On February 6, 1781, he struck a soft ramrod several times on one end while it was held parallel to a needle of a surveyor's compass. He reversed it and similarly demagnetized it. Then he noticed that placing the rod perpendicular to the needle gave no such effect. This is a modern notion called Ewing's principle. The great philosopher adds, "from this does it not seem very probable that during the concussion of the stroke and whilst the magnetic particles of the rod were more disengaged from the surrounding mass the active power above mentioned seized them and arranged them properly, when being confined, the rod afterwards remained magnetized. All this is nevertheless little more than conjecture until confirmed by further experiment."

He invented a wooden hygrometer in 1782, concerning which Robert Adrain, professor of mathematics at Rutgers, Columbia and Pennsylvania, wrote a generation later.

All this time he was in the clock making business, as witness this advertise-

[1] See T. D. Cope, *Journal* of the Franklin Institute.

ment, Philadelphia, May 20, 1786, in *Dunlap's Advertiser:*

> Wanted—an ingenious lad not exceeding fourteen years of age of a reputable family as an apprentice to learn the art and mistery of making clocks and surveying instruments. Any lad inclined to go an apprentice to the above trade, the terms on which he will be taken may be made known on inquiring of Mr. David Rittenhouse in Philadelphia or at the Subscriber's in Worcester Township, Montgomery County.
>
> BENJAMIN RITTENHOUSE

The first translation of any German play into English was Minna Von Barnhelm in England in 1786. Rittenhouse translated within a year a play of Lessing's which had an English setting. It was called "Miss Sarah Sampson, or The Unhappy Heiress." Rittenhouse's translation is called "Lucy Sampson," with the same sub-title. He also translated the "Idylls" of Gessner from the French. The *American Magazine* published his drawing of the Ohio Phyle Falls. Besides this, he was greatly interested in any fiction that he could get his hands on, feeling that it was very stimulating to his imagination. It would make a very interesting bookshelf, had we placed there his favorite fiction and on another shelf, of probably equal size, his philosophical and mathematical reading list.

On the stormy night of Franklin's death in 1790 Provost Smith wrote impromptu:

> Cease, cease, ye clouds, your elemental strife!
> Why rage ye thus, as if to threaten life?
> Seek, seek no more to shake our souls with dread!
> What busy mortal told you Franklin's dead?
> What though he yields at Jove's imperious nod?
> With Rittenhouse he left his magic rod!

President Washington appointed David Rittenhouse the first director of the United States Mint on April 14, 1792, and he remained in charge of the mint until June, 1795, when declining health compelled him to resign. Mr. Barber, late engraver of the mint, executed a bronze model of Dr. Rittenhouse. Possibly excepting Duvivier's head of Washington after Houdon, it can not be surpassed in the cabinet. "The engraver had a very fine subject and treated it in the highest style of art." The United States Mint was authorized by an Act of Congress, April 2, 1792, just twelve days before Rittenhouse's appointment. Soon afterwards, a lot of ground was purchased on Seventh Street, near Arch, and appropriations were made for erecting the necessary buildings. In an old account book, we find an entry on the thirty-first of July, 1792, of the sale of some old materials of the still house which had stood on that lot, for seven shillings and sixpence. This sum of money "Mr. Rittenhouse directed should be laid out for punch in laying the foundation stone," which cornerstone was laid by David Rittenhouse as the director of the mint on that same day. Coinage commenced the following October. This was of silver half-dismes, of which Washington makes mention in his address to Congress, November 6, 1792, as follows: "There has been a small beginning in the coinage of half-dismes; the want of small coins in circulation calling the first attention to them."

In the years 1792 and 1796 Rittenhouse and Jefferson worked out a definite scheme for making a standard foot, a definite part of the length of a pendulum, ticking seconds in the latitude of Philadelphia. A system of weights and measures on the decimal scale was admirably devised, preserving most adequately the common measures known and used by all. This measure was finally passed after a most interesting debate in May, 1796, but the Senate had

adjourned without concurring, so we still have ninety-six kinds of bushels in the United States.

In the latter part of June, 1796, Rittenhouse during several very hot days gave personal attention to the drawings from the wheel in the canal lottery. His meteorological diary shows his hand growing weaker, until on the 26th of June the entries cease. On June 27, 1796, Moreau de Saint Mery, who had been king of Paris for a day, had been refused a ticket to the Assembly ball because he kept a bookstore in Philadelphia and who was afterwards a provincial governor under Napoleon, writes: "Yesterday I attended the funeral rites here of the celebrated Dr. Rittenhouse, American astronomer whose loss his country most justly mourns. He was buried in the floor of the Observatory which he had had constructed in his own Garden. What a philosophic union, perishable ashes with an edifice consecrated to the observation of the most sublime marvels of nature! What a rapprochement between the genius of man and his nothingness!"

Finally, on July 4th, 1796, another hand again writes the entries in the diary that was David Rittenhouse's, and the record goes on seemingly as before.

THE DEVELOPMENT OF SOCIOLOGY

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I. The Movement for Social Betterment and the Origins of Sociology

While the problems with which sociology concerns itself have been discussed by philosophers since the days of Oriental antiquity, sociology first definitely appeared, properly christened as a specific department of social science, about the middle of the nineteenth century. A large number of factors contributed to its origins, among them the growing interest in man and society and an increasing knowledge of the nature of man and his physical environment. Probably the most important influence creating sociology was, however, that general groping for social betterment which was produced by the misery that came in the wake of the industrial revolution and the factory system.

In the writings of certain early sociologists, this impulse to social betterment emerged in concrete utopian plans for a more happy and perfect system of social and industrial relations. With certain other writers, like Saint-Simon and Auguste Comte, it made its influence felt by suggesting that sociology should be a science of social progress. Such writers opposed sociology, thus conceived, to the well-meant but often naïve contemporary programs for social improvement.

On the other hand, such sociologists as Herbert Spencer, Ludwig Gumplowicz and William Graham Sumner were chiefly interested in developing the science of sociology to furnish irrefutable proof of man's inability to improve his social surroundings through any conscious effort at an artificial redirection of the trend of social evolution. It is apparent, therefore, that with both the enemies and friends of social reform it was this urge to social reconstruction which gave rise to the science of sociology.

II. The First Period of Sociology: Analogy, Definition, First Principles and Systematization

The first half century or more of sociology was given over chiefly to the effort to bring about a transition from social philosophy to social science. During most of this period writers approached the subject of social origins and social processes primarily from the standpoint of dogmatic *a priori* assumptions, sweeping generalizations and heroic efforts at systematization and at a synthesis of sociological information.

The first generation of sociologists after Auguste Comte were influenced chiefly by the effect of Darwinism upon social science. One school devoted itself mainly to an elaboration of the analogy between the individual organism and human society. These writers endeavored to show that human society exhibited in its organization systems of organs possessed by the individual biological organism. While often grotesque in matters of detail, this body of doctrine was of significance for social science in the way of emphasizing the necessity of a proper coordination and harmony between the various constituent groups of human society.

The other group of early biological sociologists devoted their attention primarily to illustrating the alleged analogies between biological evolution and social evolution, laying stress chiefly upon the similarity between the strug-

gle for existence in biological evolution and the function of war in social evolution. This school of so-called "Social Darwinists" contended that in the same way that the struggle for existence had been the dynamic factor in the evolution of organisms, so war had been the chief constructive process in the evolution of humanity. It must be pointed out, however, that Darwin himself never sanctioned any such sociological interpretation of his evolutionary theories, and the title "Social Darwinism" was appropriated by this group without the approval of Darwin himself.

While enormously overemphasizing the importance of a single social process, this school made an important contribution by pointing out the very great services of war in bringing an end to tribal society and in creating the origins of the political or territorial states which were to give to society that order and security essential to the further progress of civilization.

A large group of writers were dissatisfied with this tendency to be absorbed either in elaborating the analogies between the organism and society or in emphasizing the social significance of human warfare. They turned to: (1) a discussion of the scope and methods of sociology and of its relationships with the natural sciences and the other social sciences; (2) definitions of its chief concepts; and (3) the clarification of its province.

The so-called methodological discussions which this trend in sociology produced gave rise to much heated altercation between the exponents of these diverse interpretations of the nature, purpose and methods of sociology. It absorbed a great deal of energy in the somewhat sterile and unproductive task of definition, classification and demarcation, but there is no doubt that the net result was a clarification of the sociological atmosphere and a more general agreement as to the subject-matter and objectives of sociology. In other words, this sort of work represented the inevitable and essential preliminary period of definition and classification which marks the early stages of all science, natural or social. Certain writers, such as Georg Simmel and Albion W. Small, devoted their lives chiefly to these problems of definition and methodology.

Paralleling these battles over definitions and methods was a comparable conflict among the sociologists as to the basic factor in the social process and the key to the development of a system of sociology. For example, Gabriel Tarde contended that the elementary social facts were to be located in the process of imitation; Emile Durkheim maintained, on the contrary, that the key to society lay in the impression of the group mind upon the individual psyche; Alexander Sutherland, Prince Kropotkin and others defended the assertion that the vital fact in the social life of man was to be found in sympathy and mutual aid; Gumplowicz and his disciples expounded the opposite thesis that it was in war and social conflict that one was to look for the core of the social process; Franklin H. Giddings asserted that in the consciousness of kind and differential reaction to stimulation one could discover the only valid basis for the construction of the principles of sociology; Gustav Ratzenhofer and Albion W. Small found in human interests the only rational clue to an understanding of social activity and organization; and Guillaume De Greef and Alfred Fouillée defended the contention that contractual relationships between individuals and societies constituted the *rationale* of society.

The debates thus generated gave rise to a large amount of acrimony and personal recrimination, but they stimulated each writer to the most effective defense of his particular thesis, with the resulting enrichment of our knowledge of the

nature and potency of all these very important social influences and processes. The discriminating sociologist of the present day takes little stock in the all-sufficiency of any one of these unilateral views of society, but they each helped to create that body of subject-matter out of which a reliable synthesis can now be constructed. The growing recognition of the inadequacy of single-track interpretations of the social process has likewise produced that salutary and desirable tolerance among sociologists which was so notably lacking a generation ago.

The fourth significant characteristic of this earlier stage of sociological science was the effort of the leading writers to achieve a comprehensive systematization of sociological theory. Auguste Comte's system was given over chiefly to a comprehensive philosophy of history and an elaborate plan for the future reorganization of society along the lines of what he believed to be scientific principles. Herbert Spencer devoted himself to an attempt to interpret the origins and organization of society in terms of his particular formulae of cosmic evolution, incidentally giving some attention to the analogy between the organism and society and demonstrating to his own satisfaction the futility of social uplift. Lester F. Ward, taking his departure from Comte, exploited the terminology of natural science, particularly that of botany, to prove the original supremacy of the female sex and to demonstrate the possibility and desirability of conscious social reform guided by an ever-improving body of sociological knowledge.

Giddings, more eclectic and less dogmatic than these earlier writers, exploited and synthesized the great majority of sociological writings prior to his time in what was the most impressive and comprehensive system of sociology formulated prior to the opening of the present century. His particularistic emphasis upon the consciousness of kind was worked in as the primary item in a broad view of the origins and processes of society. Ratzenhofer and Small constructed a system of sociology about a classification and schedule of those vital human interests which give rise alike to individual activity and the organization and struggles of human groups. Hobhouse salvaged from the wreckage of the organic analogy the basic fact of the desirability of a harmonious coordination of social groups and classes and argued for a growing control by human knowledge and the human mind over the processes of social evolution. A similar point of view was elaborated by Ludwig Stein in Germany. One of the latest efforts at a system of sociology, that by Professor Franz Oppenheimer, is constructed upon an exploitation of the history of human society and the economic elements in the conflict of social classes. The most elaborate recent system of sociology is that of Dr. Leopold von Weise. He regards sociology as a study of the social process, conceived of mainly as "inter-human" relationships and behavior.

It is now very generally conceded that most of these efforts to produce comprehensive and finished systems of sociology were premature. The knowledge upon which a fairly secure synthesis could be built was not available when most of these writers formulated their concepts. Further, it is doubtful if the energy or mentality of any individual is adequate to a thorough mastery of the vast range of facts essential to sociological synthesis. Nevertheless, these early systems of sociology were in no sense a total loss. They called attention to the general nature of sociological material and vindicated for all time the importance of the sociological type of analysis. They also provided the point of departure for subsequent discussion and criticism.

III. Contemporary Sociology and the Trend of Specialization

In the place of ambitious efforts at an all-embracing synthesis of sociology in the form of closed systems, the dominant trend in sociological science since about the opening of the twentieth century has been toward the splitting up of sociological endeavor among various groups of scientific men interested in one or another phase of the social process. Some have given their attention to a consideration of the problems of an adequate sociological methodology. Others have become interested in the relation between the physical environment and social processes. Another group has devoted itself to a consideration of the bearing of the facts of modern biology and genetics upon the origins, organization and future of human society. A large number of writers have surveyed and analyzed the wide range of psychological factors affecting the groupings and activities of men.

Another school has applied its efforts to a reconstruction of the course of cultural and social evolution. They have traced out the various stages in the development of the present-day forms of social organization and cultural expression, indicating as far as possible the various factors which have brought about the transition from the cave-dweller to the modern urban tenant, with all the social and cultural implications involved in this transformation. Then, the problems of social organization have attracted the attention of a large and active corps of workers in the sociological field. Finally, perhaps the most diverse and enthusiastic contribution to the literature of sociology is to be found on the part of those who are attempting to use the facts assembled by social science in the last century as the basis of more reliable and convincing plans for social and economic reconstruction than could be offered by the Utopian Socialists of the age of Robert Owen.

The progress of scientific method and specialization in the field of sociology can be well illustrated by the advances within each of these divers fields of approach to sociological analysis. In the first place, there has been an enormous improvement in the last twenty-five years with respect to both the exactness of method and the depth of knowledge possessed by the so-called specialists in particular fields of sociological study. In the second place, the process of specialization has been carried on so as to embody specialization within specialisms. For example, few social scientists would to-day contend that it is possible for them to master all the geographical factors affecting human society or all the biological processes which are of significance to the sociologists. It has become necessary, in other words, for the anthropogeographer or the social biologist to specialize upon a certain restricted range of problems and interests within his particular field.

In the cultivation of sociological methodology the first generation of students was absorbed chiefly with problems of definition, classification and the demarcation of the province of sociology. At the present time, this sort of work has been almost entirely abandoned, and we find those interested in methodology concerned with such problems as the application of statistical measurement to social processes, the analysis of the methods and limitations of the cultural approach to social origins and social organization and the consideration of the methodology essential for the study and comparison of the intelligence and social interests of definite human groups and cultures.

In other words, the generalized study of methodology has been supplanted by an examination of the utility and limi-

tations of particular and relatively exact methodologies. The important fact is that all of them insist upon an ever greater utilization of the exact quantitative methods of natural science and a relative abandonment of the *a priori* and deductive technique of social philosophy. There is a general agreement that sociology can become a true science of society only in the degree to which it is able to appropriate and apply those exact methods of measurement and analysis which constitute the indispensable attributes of science in general. William F. Ogburn and his sympathizers and followers have been especially earnest in emphasizing this point.

In studying the absorbing and stimulating problem of the effect of the multifarious influences of the physical or geographical environment upon man in human society we find a corresponding progress away from sweeping and dogmatic generalizations and towards concrete study of the influence of particular geographical factors upon specific groups of men dwelling in well-defined geographical regions. The older anthropogeographers, from Ritter and Peschel to Ratzel, Reclus, Kirchhoff and Semple, attempted to present a systematic and comprehensive survey of the operation of all the so-called geographical "influences" upon man and society. With the progress of knowledge in this field, it became more and more difficult, however, for a single student to master all the facts involved in the various phases of the incidence of the environment upon man. Hence, we discover a growing tendency towards the specialization of writers upon some single type of geographic factor, such as climate, topography, routes of travel, waterways and routes of water communication, meteorological factors and alteration of geographic influences by the progress of the material culture of man.

But this is not all. Following the suggestions of the great French geographer, Paul Vidal de la Blache, and his disciples in other countries, the most advanced school of anthropogeographers have even come to doubt the feasibility of a generalized study of any one of these special geographic factors or influences. They contend that anthropogeography can become truly scientific only through an exclusive concentration upon the study of the effects of specific geographic factors upon a group of men inhabiting some very definite geographic region. In other words, regional physical geography has been followed by recognition of the inevitability and necessity of regional anthropogeography.

Further, the modern scientific anthropogeographer no longer proceeds from the naïve assumption of geographical determinism, but adopts the cultural point of view of the modern critical anthropologist and cultural historian. He recognizes that human culture is the dynamic element in society and civilization, and simply endeavors to discover the particular ways in which culture is conditioned by the geographical factors operating upon the inhabitants of the particular region studied. When one compares such a summary of the contemporary point of view as Lucien Febvre's "Geographical Introduction to History" with one of the best syntheses of the older generalizing anthropogeography, such as Miss Semple's English adaptation of Ratzel, he realizes the extent of the progress made in this field in the last generation with respect to both the degree of specialization and the precision of methodology.

The same advances toward detailed specialization and greater exactness of scientific method is to be observed among the biological sociologists. We have already pointed out that the first generation of biological sociologists concerned themselves primarily with an elaboration of such hypothetical analogies as the theory of the social organism

and the doctrine of Social Darwinism. There was little effort to study in a scientific fashion well-founded biological processes and to discover through detailed observation their bearing upon the problems of human society. Such interests and activities as characterized biological sociologists thirty years ago have now become thorough anachronisms in the field.

In the first place, we have the demographers, represented by such men as Willcox, Thompson and Kuczynski, who are interested in gathering and classifying the facts descriptive of the social population, thus collecting the raw material for theoretical students of the problem. Along with these we have the students of the theory of population. They take their cue from Malthus and are known in general as Neo-Malthusians, primarily because of their reliance upon birth control, which Malthus had refused to sanction. These writers, well represented by Professor East, author of "Mankind at the Crossroads," are concerned with the quantitative aspect of population, namely, (1) the relation between the increase of population and the means of subsistence, and (2) the bearing of this situation upon the prosperity and progress of human society. They are, in general, sympathetic with the birth control movement as led by Mrs. Sanger and others, holding that the chief avenue to social well-being is to be found mainly through some practicable method of maintaining the population at the level which will insure a relatively high standard of living, assuming the existence of an adequate technology and an efficient economic system. Certain members of this school have endeavored to formulate laws of population, qualifying or supplementing the original generalizations of Malthus.

Another important group of writers concentrate their attention upon the qualitative aspects of the population problem. They are concerned with the biological evolution of man, the question as to whether civilization has had a disastrous effect upon the biological quality of the human race, and the whole issue of eugenics, involving the problem of the possibility of the artificial improvement of the physical quality of the human stock. Writers like Otto Ammon, Karl Pearson, Edwin Grant Conklin and Samuel J. Holmes represent discriminating scientific exponents of this point of view, which has been set forth in a more popular and exuberant fashion in the writings of Mr. A. E. Wiggam.

Finally, there should be noted the physical anthropologists and the scientific students of race and racial characteristics. Such scientific men devote themselves to the ascertainment of the physical criteria of race and to the accumulation of exact facts with respect to the physical traits of the major races of mankind. In carrying their researches beyond physical investigations to an analysis of the mental traits of the various races, they link hands with the differential psychologists. The work of the physical anthropologists, admirably represented by men like Arthur Keith, Rudolph Martin and Aleš Hrdlička, together with that of the differential psychologists and the cultural historians, offers the best possible antidote to the vagaries of Madison Grant and his disciples who have been busy in recent years disseminating the Nordic rehabilitation of the old Aryan myth.

These various groups of scientific students of the biological foundations of society are at last making available the relevant facts and processes of biology, so that they may be appropriated in an intelligent fashion by the alert legislator and discriminating social worker. Only superstition and bigotry prevent us today from undertaking a speedy adoption

and application of their more significant and demonstrably valid recommendations.

Psychological sociology likewise had its origins in the last quarter of the nineteenth century with writers who dealt in broad and sweeping dogmatisms concerning such complex and general psychological factors as custom, imitation, fashion, impression, emulation, sympathy, etc. At this time there was little or no reliable technical psychology to be learned, and these writers possessed but a slight familiarity with even such psychology as existed. While some progress took place in the interval between 1890 and 1910, as exemplified by the sociological interests of psychologists like Baldwin or the better mastery of psychological principles by a sociologist like Cooley, it may safely be said that the first treatise on psychological sociology which demonstrated the author's comprehensive familiarity with the facts of reliable psychology was C. A. Ellwood's "Sociology in its Psychological Aspects," published in 1912. W. I. Thomas's mastery of social psychology had been demonstrated mainly by a number of erudite articles and monographs.

Yet this ambitious attempt at synthesis to be found in Professor Ellwood's useful book did not set the pattern for the development of psychological sociology in the next decade. Rather, we find an altogether commendable tendency toward further specialization and a more thorough cultivation of technical psychology. The popularity of the instinct hypothesis, launched by the appearance of Professor McDougall's book in 1908, has provoked a vast amount of controversy and has resulted in a general clarification of this problem, the best synthesis now existing in the field being Professor Bernard's monograph on "Instinct." The behavioristic impulse, emanating from Watson and Max Myer, has been exploited for social psychology by Allport, Burnham and a number of others who are interested in the important social applications of the theory of the conditioned-reflex.

The social significance and applications of Freudianism have been examined and exploited in a discriminating fashion by Martin, Groves, Ogburn, Holt and Thomas. An extremely promising effort has been made to work out the all-important synthesis of behaviorism and Freudianism by Allport, Martin, Hamilton, Young and others, a development which has been hampered by the vigorous rhetorical, but somewhat illusory, opposition of Watson to Freudianism. The psychology of the crowd is now beginning to be studied in a scientific fashion by Martin and others. The significance of habit-forming complexes for psychological sociology has been indicated in detail by Ellwood, Dewey and Gault. Wundt, Hall, Lévy-Bruhl, Paul Radin, Goldenweiser, James Harvey Robinson and others have devoted themselves to a study of the psychological history of the race, clarifying the similarities and contrasts between the thinking of primitive and modern man.

The provision of scientific and practicable methods of mental testing by Binet, Simon, Goddard, Yerkes, Terman, Otis and others has made possible the development of differential psychology, a technique of the greatest significance for the further analysis of the problems of eugenics, mental hygiene, criminology, immigration and democracy. Finally, the necessity of abandoning a theory of psychological determinism and adapting the psychological theories of society to the notion of cultural conditioning has been recognized by nearly every group now interested in psychological sociology. The most ardent exponents of this point of view have been the critical anthropologists of the Boas school, and Graham Wallas, F. C. Bart-

lett, W. I. Thomas, C. A. Ellwood, W. F. Ogburn and F. Znaniecki.

The net result of these labors has been to put at our disposal a vast body of relevant psychological information of the greatest practical significance for human betterment and a more adequate and penetrating conception of social processes. Nothing could more effectively illustrate the progress in psychological sociology in the last generation than a comparison of such books as Gustave Le Bon's "The Crowd," or Gabriel Tarde's "Laws of Imitation," with Allport's or Young's "Social Psychology."

In the study of the history of human society there has been notable progress away from the *a priori* philosophy of history characteristic of the early stages of historical sociology. Building upon the firm foundation of the laws of cultural development established by the critical anthropologists and upon the vast array of facts concerning social and cultural evolution gathered by the conventional historians, the students of social and cultural history have been able to work out a most impressive survey of the history of human culture from the Old Stone Age to the Hoover prosperity. There has been an escape both from the inaccuracies of the old philosophy of history and from the irrelevancies of the episodical and anecdotal historians of the conventional academic school of history-writing. In this field, as in others, specialization has been necessary, as no single student of social evolution could personally master the technical equipment or the body of facts involved in a survey of the totality of human cultural development.

The study of the facts and problems of social organization has attracted a varied group of authorities. The forms of social organization have been discussed in great theoretical detail by Georg Simmel. Simmel's conclusions have been made intelligible, as well as accessible, to English readers by his disciple, Dr. N. J. Spykman. The biological basis of social organization has been analyzed by writers such as Gini, Pearson, Carr-Saunders, Ammon, West, Holmes, Kelsey and Hankins. Tarde, Durkheim, Wallas, Cooley, Ross, Ellwood, Bernard, Bogardus, Young, Williams and others have devoted their attention to the psychological factors involved in the organization of society. The economic aspects of the question have been investigated by Loria, Sombart, Weber, Schmoller, Webb, Hobson, Hammond and Cole, by Veblen and the institutional economists, and by Professors Seba Eldridge, Charles Austin Beard and others interested in the economic basis of politics. The political foundations of social organization have received especial attention from Gustav Ratzenhofer, Robert Michels, Graham Wallas, Harold Laski, Albion W. Small, A. F. Bentley and F. H. Giddings.

The most significant fact about all these modes of approach as specialized forms of analysis of social organization is that the old obsession with definition and classification has been superseded by a concern with the vital and dynamic processes involved in the origins of social groups and their mutual conflicts and adjustments. Much of the credit for this wholesome change is due to Ratzenhofer and Small.

The reaction of these various phases of progress in scientific sociology upon social work and social reform has forwarded the ultimate realization of the ambitions of the founders of sociology to create a scientific guide for the betterment of mankind. On the whole, social work has abandoned the ideal of amelioration and has adopted the slogan of prevention, the key to which is to be derived from a mastery of the scientific facts of sociology.

Sociology, properly understood, does not discourage "uplift." Indeed, it

would seem that the chief vindication of sociology is its real potential service to the cause of increasing the happiness and prosperity of human society. What sociology does insist is that uplift shall cease to be governed by theological and sentimental motives and shall found its objectives and methods upon the indisputable facts wrought out by sociology in the last quarter of a century.

The extensive advances in the subject-matter of sociology, as well as the increasing tendency towards specialization, which have been all too briefly summarized in the preceding paragraphs, make it obvious that the future of sociology must decisively be a co-operative matter. Any synthesis of the field by a single individual is doomed to result in either grotesque inaccuracies or in the superficialities compatible only with a brief text-book survey of the field.

IV. The Influence of Sociology upon the Special Social Sciences

We should at least make passing mention of the influence of sociology upon the other social sciences. Its effect upon the study of history has been chiefly to emphasize the fact that man does not function as an individual but as a member of a group; to aid the progressive historian in his analysis of the various forms of institutional life in which man participates; and to emphasize the conception of civilization as a genetic and dynamic process. Sociology has been particularly useful in promoting a broad and synthetic view of the processes of historical causation.

Sociology has been able to offer a number of helpful suggestions to open-minded economists, for example: emphasis upon the group basis of custom and fashion which determine to so large a degree the nature of economic demand; an indication of the interrelation of the economic with the other factors in the social process; and a clarification of the nature of the social institutions which condition the operation of the economic factors in society.

On no other special social science has the influence of sociology been more significant than with regard to political science. Sociology has furnished indispensable information as to the nature and foundations of political control and has cleared up many obscure problems related to the origins of the state. It has also given a real *rationale* to politics by indicating the social process which goes on within the state and by making it clear that the real function of the state is to act as an umpire of this social process. The influence of sociology upon jurisprudence is comparable to that upon the science of government. Sociology has emphasized the social origins and function of law; has indicated the fundamental social basis of all valid legal principles and has emphasized the function of progressive jurisprudence in the way of social engineering and the guidance of social change.

The sociological influence upon ethics has been revolutionary in theory, however little it may have affected conduct in practice. It has made clear the group basis of all ethical guides and criteria, however dogmatic a social group may be with respect to the allegation of the divinely revealed nature of its ethical concepts and practices. Sociology has also emphasized the necessity of adopting a secular basis for the judgment of commendable conduct. It insists that the object of ethics should be to produce an ever greater number of happy and efficient human beings here upon the earth, and not to save a vast throng of souls eagerly quitting their earthly misery.

The relationships between sociology and esthetics have not been adequately cultivated thus far, but the group foun-

dation of esthetic judgments is readily apparent, and enough has already been done to indicate the real importance of art as a form of social expression and a mode of social control. With the gradual secularization of human interests we may predict that esthetics will ultimately come to occupy the position held by theology in the interest and affections of the early sociologists.

The most important general effect which sociology has had upon all the special social sciences is to emphasize continually the unity of the social process and to promote a synthetic point of view on the part of all types of social scientists. This guards against the narrowness and superficiality which invariably accompany a partial view of the processes and institutions of society.

V. Obstacles to the Development of Sociology

In spite of the remarkable strides which sociology has made in volume of subject-matter and increasing exactness of its methods, it has made relatively slow progress in achieving academic recognition, in receiving adequate consideration from legislators and public officials, and in securing the good-will and confidence of the general reading public.

There are a number of causes of this situation. The first might be called the "euphonistic" obstacle, namely, the confusion of sociology with socialism because of the similarity in the pronunciation of the two words. This may seem preposterous, but the writer believes it to have been more important than any other influence in prejudicing the average timid and conservative citizen against sociology. Even the librarian of one of our foremost graduate schools in this country fiercely opposed sociology and sociological books for a generation because of his firm belief that a socialist and a sociologist were one and the same person in each and every case.

In the second place, we must consider the opposition of pure and pious folk, who look upon sociology as a subject which undermines morality and leads to atheism. When properly taught, sociology must of necessity provide the foundation for any valid body of morality or any social religion. It is true, however, that sociology analyzes with frankness and candor the anachronisms in the present moral code and Fundamentalist religion. Hence the alarm with which half-educated people view the teachings of sociologists.

At the same time, these "vile" sociologists, as they appear to the late Mr. Bryan and not a few college professors, are viewed with a mixture of amusement and pity by those in real touch with life and its problems. There is no doubt that three fourths of our American academic sociologists would read such an innocuous if illuminating book as Miss Kirchwey's "Our Changing Morality" or Professor Joad's "Thrasymachus" with unmitigated horror and disgust. Over half of them would gladly lock arms with the late Wayne Wheeler and John S. Sumner. Likewise, most of them are thoroughly "sold" to the capitalistic system and the "theories of the leisure class," a fact which removes them from active contact with the campaign for social and economic reconstruction.

Hence, those on the "firing line" of cultural, social, economic and ethical advance will have nothing to do with the majority of the sociologists. What appears to the pious and respectable as unmistakable proof of depravity and revolutionary radicalism on the part of sociologists seems to the realists and reformers to be nothing less than pedantry, ignorance, prudery, hypocrisy or infantile timidity.

Another recent form of opposition to sociology arises from progressives who fear the alleged pernicious influence of

foundations and endowments. Much current sociological research is subsidized by the great foundations which have been endowed by very wealthy men interested in preserving the existing social, economic and political order. Naturally, most subsidized research must carefully avoid projects likely to result in unsettling discoveries, or, if such results do emerge, they must be obscured. Such considerations, as Benjamin Stolberg has amply indicated, hamstring both scientific candor and the practical value of sociological research.

Again, we must list among the powerful sources of opposition to the progress of sociology the jealousy of the other social sciences. History, economics and political science were established as academic subjects from a half century to a century earlier than sociology. This has given them a stronger hold upon the faculties and administrative boards of the colleges and universities. The opposition of these older vested interests to sociology has been intensified by the fact that the vivid human appeal of sociology has attracted to sociology courses large numbers of students who would otherwise have been swelling the class registers and enhancing the local prestige of solemn and respectable teachers of history, political science or economics. Therefore, in certain institutions, such as Princeton, Harvard, California, Cornell and Johns Hopkins, together with most of the aristocratic New England colleges, sociology has been excluded altogether or has been offered in an inadequate and misleading fashion by professors of economics. In many institutions, such as Wisconsin, while courses in sociology are tolerated, the instructors in sociology have been kept under the general control of the department of economics or government. To the opposition of the vested interests of the older social sciences must also be added the even more vigorous antipathy of the departments of mathematics, science, literature and other even older and more respectable departments and vested curricular interests.

The future of sociology is a matter for prophecy and not for history, and we are only concerned in this article with history. The place that sociology will occupy in the future of human thought and action will depend upon a multitude of factors, some connected with sociology itself and others with general trends in the public mind.

Before sociology can command the unqualified respect and support of intelligent and thoughtful persons it must divest itself of a sentimental adherence to indiscriminate efforts at uplift; it must reject whole-heartedly the impurity-complex which it has inherited from its Puritan and ministerial ancestry; and it must reduce the paralyzing influence of discipleship and dogmatism to which all the social sciences are in differing degrees susceptible. The degree to which it will influence social thought and action will also depend upon how far society surrenders its contemporary submission to rhetoric, convention, tradition and propaganda, and demands competent technical and scientific guidance.

If it be objected by many that sociology has not yet secured a sufficiently high level of agreement among its various schools, and that it has not yet perfected its methodology with adequate scientific precision, it may safely be answered that it will probably remedy these defects long before society will be willing to accept its constructive assistance.

SCIENCE SERVICE RADIO TALKS

PRESENTED OVER THE COLUMBIA BROADCASTING SYSTEM

STEEL WITHOUT RUST

By Dr. JOHN JOHNSTON

DIRECTOR OF RESEARCH, UNITED STATES STEEL CORPORATION

THE fact that iron and steel rust under many of the usual conditions of service is only too well known to all of us; it is less widely known that the loss due to rusting each year is, as estimated by competent authorities, to be reckoned in terms of millions of tons of metal and in hundreds of millions of dollars. The properties of steel are so valuable, indeed so unique, that the world wishes to use it for all sorts of purposes, and so tries to offset its tendency to rust by applying to the steel surface some sort of protective coating. Familiar examples are: by electroplating the steel with copper, nickel, chromium or other metal; by coating it with another metal, with tin, as in the familiar tin can, or with zinc to make the so-called galvanized iron, or with lead; or with a glass or vitreous enamel, as in the familiar enamel-ware; or by covering the surface with paint or tar or other similar materials. But none of these coatings designed to protect the steel from the ravages of the rusting agents—principally oxygen and water acting together—is entirely satisfactory, and a very great deal of effort has been expended in endeavoring to secure improved protective coatings on steel at a reasonable cost.

A great deal of effort has also been put forth in experimental work aiming to lessen the rate of rusting of iron by addition of alloying elements, with little success except in two instances, both discovered some 20 years ago. First, the presence of about ¼ per cent. copper in steel slows down markedly its rate of rusting and destruction in the atmosphere, and has proved to be especially advantageous in steels exposed to industrial atmospheres, as in and near cities; this type of steel, which is sold as copper-steel and also under various trade-names, costs little more than ordinary steel, slows down the rate of rusting in the atmosphere, but is not rustless. Second, the discovery was made that addition of chromium to the extent of 12 per cent. or more renders the iron substantially rustless under many conditions of use. This was a rather surprising discovery, for chromium is not inherently a noble metal in the sense that gold and platinum is: indeed, it is really less noble than iron, but has the power of covering itself, rapidly and automatically, with an invisible, very thin, oxide film which, when formed, protects the metal underneath from further attack. It retains this power of forming a protective, impervious, oxide film even when alloyed with iron, provided that the alloy comprises more than about 12 per cent. chromium; and this is the basis for all the recent rapid development of the so-called stainless steels, their stainlessness being in all cases due to the chromium which they contain.

It is of interest to note that the element chromium had been known for more than a century before it was really put to work, as a metal, for the world. This delay in making use of chromium is due in part to the comparative diffi-

culty of extracting it from its ores, but mainly to the presumption that it would exhibit no outstandingly valuable properties. Moreover, it was thought of as rare, but its ores prove now to be at least as abundant in the earth's crust as are ores of copper, and to be much more plentiful than ores of lead or of tin, all of which are not usually thought of as rare metals. It is true that chromium still is—and is likely to continue to be—rather expensive as compared to the wonderfully cheap metal iron, and therefore that steels containing enough chromium to render them stainless must inevitably cost considerably more than ordinary steels. But stainless steels, which now cost no more than ordinary steels cost a century ago, render special service, which for many purposes justifies their extra cost.

This group of steels is substantially rustless under nearly all ordinary conditions of use; to be precise, these steels are rustless under oxidizing conditions, as in the atmosphere, provided that the final heat treatment of the alloy was carried out in the appropriate manner. They are, however, not entirely resistant under some conditions of service; but no metal can be expected to withstand corrosion completely under all conditions of environment—even the noble metal gold or platinum is not entirely resistant in all places where we might wish to use it.

The rustless or stainless steels and irons may, for convenience in this brief discussion, be divided into three fairly distinct groups.

The first group, and the earliest in point of time, comprises the stainless steels which are properly called steels because they are hardenable upon appropriate tempering. They contain 12 to 14 per cent. of chromium with relatively high carbon, and are used mainly for cutlery.

The second group comprises the stainless, low-carbon steels, or, more properly, irons, because these alloys are not hardenable by heat-treatment; they usually contain about 17 per cent. or more of chromium and relatively low carbon. They are rustless under many circumstances but not entirely satisfactory under the severest conditions of exposure; their use is therefore limited largely to special industrial applications.

The third group, which is the group arousing the greatest interest at the present time, comprises the alloys containing nickel as well as chromium and iron. The most commonly used contains about 18 per cent. chromium and about 8 per cent. nickel, with relatively little carbon; it is often called simply 18–8, but bears a great variety of tradenames. It is one of the group of so-called austenitic stainless steels, the term austenitic referring to the fact that in this group the iron is caused, through the influence of the alloying elements, to be present at ordinary temperatures in the austenitic, or gamma, non-magnetic crystal form.

In this connection it may be noted that the uniqueness of steel as a useful metal, the fact that it can be tempered and so readily made hard or soft, ductile or brittle, depends primarily on the circumstance that iron is the only common metal which readily assumes either one or other of two different crystal forms. These two forms differ markedly in specific volume, the change of volume being obvious when one transforms into the other; in heat-content, so that there is an evolution of heat—the so-called recalescence—when the gamma form passes over into the alpha form; and in their capacity for holding in solution carbon and other alloying elements; indeed, they behave almost as two different metals, though composed of the same iron atoms in different arrangement. The properties of the finished steel article are controlled by controlling the occurrence of this transformation. This

heat-treatment of steel is, of course, a very ancient art, long kept secret by those who practiced it; its basis has been understood only in very modern times and the art has become a science open to any one.

To return now to the austenitic type of stainless iron alloy, the principal alloy of this group, namely, that containing 8 per cent. nickel as well as 18 per cent. chromium, is perhaps the most important of all the stainless types at the present time, because of its much wider applicability. It has of late been used rather widely for decorative purposes on the outside of buildings as well as on the inside for doors, for panels and trim of various kinds, and on automobiles, partially replacing chromium plating; also for restaurant equipment, kitchen utensils, hospital ware and for many other similar familiar purposes. It is being used on a considerable scale in the chemical industries, including the refining and cracking of petroleum; and with some slight modifications of composition and treatment, which now are known to obviate troubles occasionally encountered by some of those who have used it for such purposes, its use in the modern chemical industry is likely greatly to expand. It takes on a high polish, which it retains indefinitely in the ordinary atmosphere; it is ductile, yet exceedingly strong, considerably stronger than ordinary steel and particularly so at temperatures approaching red heat. Moreover, it is quite resistant to attack by oxygen at high temperatures, and so it can be used in places, such as furnaces, where parts made of ordinary steel would have only a short useful life.

The remarkable strength of this austenitic type of alloy, both at ordinary temperatures and at high temperatures, indicates that it will have an extensive field of application apart altogether from the more or less decorative uses, now familiar to us, which depend mainly upon its essential rustlessness. Its use offers possibilities of structures which for a given strength are lighter, consistent with complete safety, than if made of any other metal or alloy now used.

The development of this very useful type of alloy—a development which has resulted, directly or indirectly, from the labors of many men, in various countries—is another example of the advantage which accrues to the world from the systematic careful investigation of the potentialities of materials derivable from the raw materials available to us. Primitive man used as materials only those found naturally; for untold centuries man had to be content with a very small added number obtained by simple means from his raw materials; and it is only with the development of the science of chemistry—which began as a science about 150 years ago—that he has become possessed of a large number of new materials which have enabled him sometimes to do new things, sometimes to do old things in a better way. Yet the research worker does not, strictly speaking, create anything except values; what he does is, by painstaking exploration, using as a guide and interpreter the previous accumulation of experience known as science, to discover just what properties are inherent in substances of one kind or another, and how to combine them to get a useful result. This becomes a new technical advance if, after suitable development—which is usually expensive both in time and in money—it can be realized at a price the world is willing to pay for it. In the case of the stainless and rustless steels and irons, all of which contain at least 12 per cent and usually 18 per cent. or more of the element chromium, this development has now proceeded to a point at which the world is increasingly ready to pay for them, by reason of the remarkable properties possessed by these alloys.

WHAT DO YOU WEIGH TO-DAY?

By RALPH W. SMITH

CHIEF, SECTION ON WEIGHTS AND MEASURES LAWS AND ADMINISTRATION,
U. S. BUREAU OF STANDARDS

"What do you weigh to-day?" That arresting question, boldly lettered on a person-weighing scale, flings its challenge to a dieting world from hotel lobby, drug store, railroad station and street corner. And when it reaches you do you accept the challenge and promptly climb aboard the person weigher to resolve the doubt? You probably do, for an opportunity to weigh one's self is a lure which it seems few can resist.

The importance of these scales has recently become so great that their proper regulation was one of the subjects discussed at a recent national conference of weights and measures officials—those officers whose duty it is to supervise commercial scales and weights and weighing and measuring in general. A code of specifications and tolerances was proposed which would require scales intended solely for the weighing of persons to be as accurate as scales of similar general characteristics used for the buying and selling of merchandise. Person weighers would also be required to have what is known as a "free zero"; that is, the construction would be such that a clear and definite indication of the zero balance condition would be given at all times, so that the prospective customer may assure himself before he invests his penny that the scale is properly balanced and ready to start right from scratch.

Perhaps people will not avail themselves of this opportunity to avoid scales which are out-of-balance at zero. Too many folks seem to believe that anything which looks like a scale will give correct weighing results. I once saw a woman step blithely onto a scale, deposit her penny, read the indicated weight, and go her way entirely satisfied, when all the time there was staring her in the face a "condemned" label, four or five inches in diameter, placed squarely in the center of the scale dial by the weights and measures official to show that the scale had been found inaccurate upon test. An indicator which does not exactly coincide with the zero graduation would probably mean little or nothing to such a person. But it is a theory of weights and measures supervision to provide the customer with reasonable means to protect his interests; if the public do not avail themselves of the means for self-protection which are provided, they must suffer the consequences in inaccurate weight results.

Then there is another class of requirements in this code intended to protect the customer in spite of himself. For example, some person-weighing scales may have an ungraduated interval between zero and some fixed point, throughout which interval the scale is not designed to give weighing results. It is provided that on such a scale, if a fond mother tries to weigh her child whose weight falls within the no-weight zone, her penny must automatically be returned to her. On a scale which issues tickets showing the weights of persons weighed, it is demanded that when the scale becomes inoperable by reason of the exhaustion of the supply of tickets, any pennies inserted in the slot during the continuance of this condition shall automatically be returned, or the insertion of a coin in the coin slot shall automatically be prevented.

Numerous types of person-weighing scales are in use, but not all of these will be covered by the code of the National

Conference on Weights and Measures. For it is only when a fee is charged for the weighing service that the scale becomes "commercial" in the weights and measures sense and subject to official supervision and test. All that large aggregation of free weighers, bath-room scales, and other types on which the insertion of a coin is not a prerequisite to a weight indication, will continue to be unregulated, for it is only when the weighing assumes a commercial aspect that the state or city, in the exercise of what the lawyers term the "general police power," can step in and enforce regulatory measures.

And even the penny scale can live an untrammelled life in some communities—at least until the laws are amended. For once upon a time a clever defense lawyer, whose client was in trouble with the local department of weights and measures on a matter involving charges for laundry work at so much per pound, delved into the statutes and discovered to his satisfaction that the law specifically mentioned "commodities and things" but was quite silent about "services." He represented to the court that his client was selling neither commodities nor things but only a laundering "service," in view of which he contended that the weights and measures law did not apply to his client and his scales.

In its wisdom, the court found the argument valid and the defendant was discharged, thus excluding from the jurisdiction of that department matters having to do exclusively with service, as distinguished from commodity. The person weigher and its operation fall in this class; the scale is not intended to determine amounts of commodity bought or sold but merely performs a weighing service for the information and satisfaction of the weigher. However, when the scale charges for this service it is selling the service, and the transaction becomes commercial and subject to the supervision of weights and measures authorities wherever their authority embraces services as well as things.

Since the time of the court decision mentioned, some states have amended their weights and measures laws to include within their purview sales of service as well as sales of merchandise; fortunately, also, the weights and measures laws of all states, as originally worded, were not as restrictive as the statute mentioned. So it is to be anticipated that the ubiquitous person weigher will be regulated and supervised and tested in many states, and that the good effects of this supervision will be felt, insofar as new scales are concerned, even in those states where the present laws will not permit testing, because the manufacturers may be expected to discard from their lines models which do not conform to the requirements of the code of the national conference.

However, a public, eager to be weighed, will still have many styles to choose from, even if considerable elimination takes place. One may patronize a tall scale with a slender pillar and a large circular dial, or, if graceful curves are not appealing, one may choose a scale modeled on severe, straight lines; plate glass mirrors are available on some scales to cater to the eternal feminine and the semi-occasional male; if one prefers an atmosphere of surgical cleanliness, there is the scale finished in white porcelain and tile. Short-pillared scales, on which one looks down rather than ahead or up to read the weight indication, and which may be constructed to conceal the weight indication from all except the person being weighed, are a recent development, and in these, modernistic ideas of exterior design and unconventional color schemes will be found. Ticket machines, which for your penny tell not only your weight but also your fortune and perhaps even include a photograph of a distinguished aviator or a popular actress, may be patronized.

And now comes a foreign manufacturer with the announcement that he has developed an "all talking" scale which will announce the weight of a person, presumably in well-modulated tones. Whether or not some other manufacturer will go so far in developing the phonograph idea as to produce a scale in which the good or bad news, as the case may be, will be accompanied with appropriate advice on how to keep on getting thinner or how to build up an emaciated physique, remains to be seen. It is not clear how such a machine might be made to discriminate and select the proper advice for each of its clients, but whatever method might be used, the advice would probably be as appropriate as the "fortunes" which ticket scales now hand out regardless of sex, age or present condition of servitude.

Anyway, it has been proven that people like to "get weighed," and are willing to pay for the opportunity; and enterprising individuals are making it just as pleasant and easy and convenient as possible for people to gratify this desire. It is said that the nation has become "weight conscious." To what extent this consciousness may be charged to the designers of frocks, the manufacturers of breakfast foods, the vendors of reducing recipes and remedies and the advice of life-extension institutes can not be said.

Perhaps no small part of the tremendous volume of public person weighing is done with the laudable desire of keeping a check on one's health and general physical condition. But more fundamental than this is the unexplained but very real and deep-seated urge to get weighed, which seems to be the common heritage of most of us.

Now if you see on a person weigher a paper sticker or a metal disc or a lead plug which indicates that the scale has been "sealed" by the department of weights and measures, this means that the scale in question has been tested with test weights and found correct. But keep a weather eye open for a tag indicating that the inspector has "condemned" or "rejected" the scale upon which you contemplate weighing yourself; in such a case save your penny for some other scale, for the ominous tag means that something is wrong and that you will not get a correct weight on that scale until repairs have been made.

A penny is not much, but even so there are those who simply must weigh themselves, but who so hate to part with the customary copper that they resort to the use of slugs. Numerous coin-operated vending machines have been developed in which the mechanism ingeniously and automatically applies a series of tests to determine the genuineness of the coins inserted. Some of these machines are said to apply as many as nine or ten separate coin tests—for over and under diameter, over and under thickness, over and under weight, milled edge, rim, center hole and magnetic properties. If there is any room left inside the housing of such a machine, there would be a wonderful opportunity for using a phonograph attachment. How pleasing it would be to the customer who has made tender of legal coin for the machine to thank him graciously for his patronage; and how appropriate that a raucous reproof be administered to one who tries to beat the machine with a lead slug or a brass or iron disc.

The importance of a coin-testing mechanism is, of course, much greater in the case of a vending machine where the value of the required coin or coins is relatively large, than it is in the case of the penny scale; moreover, if the scale receives a slug this merely means a loss of profit for the operator, whereas the operator whose vending machine accepts a slug loses not only his profit but also what he has invested in the article dispensed. Yet if the loss of revenue resulting from the use of slugs becomes

sufficiently serious, it is probable that the manufacturers of coin-operated scales will follow the lead of the vending device manufacturers so as to protect the interests of the purchasers or lessees of their scales.

Finally, if you are one of those with a weight complex, and if your weight appears to vary considerably from day to day, don't be too quick to blame the scales. In the first place, errorless scales are just as rare as perfection in any other line. A scale is considered to be "correct" when its error does not exceed the allowable tolerance in either direction; it is plain that two scales might be "correct" and that yet one scale might have a minus error and the other a plus error, which would result in some difference in the weight indications on the two scales for exactly the same load. In the second place, remember that the human body is far from being constant in weight and may vary several pounds throughout a single day, depending upon the time of day, the temperature, the amount of food and drink taken into the system and similar factors. If you want a real check on whether or not you are losing or gaining weight, weigh regularly on the same good scale and do your weighing at approximately the same time and under the same bodily conditions every day. If you do this, you will know at all times just how you stand with your old friend avoirdupois.

MAKING BACTERIA INVISIBLE AND ITS SIGNIFICANCE

By Dr. J. P. SIMONDS
NORTHWESTERN UNIVERSITY MEDICAL SCHOOL

Fifty years ago on the 24th of last March, Dr. Robert Koch read a paper before the Berlin Physiological Society, in which he proved that the tubercle bacillus is the cause of tuberculosis. This was an epoch-making discovery. A year before, at a meeting of an International Scientific Society in London, he had described a method by which bacteria could be grown on solid mediums in pure culture. As soon as Dr. Koch had finished reading his paper, the great Pasteur, who was in the audience, rushed forward as fast as his partially paralyzed leg could carry him, enthusiastically shouting, "C'est un grand progrès." (This is a great advance.) Using Koch's method and applying his principles, scientific men discovered the bacterial agents which cause many of the well-known infectious diseases—diphtheria, typhoid fever, cholera and many others.

These newly discovered bacteria seemed always to form on artificial culture mediums the same type of colonies, *i.e.*, aggregations of microbes in sufficient numbers to form a visible mass, and to have the same shape and staining qualities, no matter from what source they had been isolated. Hence the doctrine of fixity of bacterial species, that is, that a species of bacterium always showed the same cultural and structural characteristics under like conditions, came to be an accepted tenet of the science of bacteriology.

This doctrine of fixity of bacterial species held undisputed sway for more than thirty years. But ten or fifteen years ago some bacteriologists began to be skeptical about the truth of this doctrine. Skepticism is a useful habit of mind in a scientific man. They observed the phenomenon of pleomorphism, that is, bacteria known to be growing in pure

culture assumed atypical and even bizarre shapes. Somewhat later it was found that bacteria descended from a single isolated parent microbe would produce on artificial culture mediums colonies that were not characteristic of the species. Some of these colonies were smooth and glistening and had regular borders; others had rough surfaces and irregularly wavy edges.

The still more startling discovery by Drs. Twort and d'Herelle of the bacteriophage was popularized by Sinclair Lewis in his novel "Arrowsmith." Bacteria that were growing vigorously would suddenly disappear in spots, giving the originally uniform, growing mass a moth-eaten or Swiss-cheese appearance. Microscopic examination of these spots or holes revealed that the bacteria had completely disappeared, or at least had become quite invisible. It was at first believed that the bacteriophage was a sort of fatal infectious disease of the bacteria themselves and caused their complete destruction.

For many years it has been known that the germs of certain infectious diseases are so minute that they can pass through a compact stone filter and are too small to be seen with the most powerful microscope. This group of germs is known as filter-passing or ultramicroscopic viruses. They cause a great number of diseases, such as the mosaic disease of plants; certain tumors and diseases of the blood of chickens; distemper of dogs; pleuro-pneumonia and foot and mouth disease of cattle; and smallpox, vaccinia, measles, rabies, influenza, common colds, infantile paralysis, and several other diseases in man.

This is the background of the very important and possibly epoch-making recent work of Dr. Arthur I. Kendall, professor of research bacteriology, in Northwestern University Medical School. The following description of this work is largely a condensed report of the lecture in which Dr. Kendall announced his new method and the result of its use.

There is a heterogenous group of formidable diseases, many of which occur as rapidly spreading epidemics, such as influenza and infantile paralysis, whose inciting agents have thus far eluded cultivation upon artificial mediums. One reason for the uniform failure to induce growth of those "viruses" outside the human body is the fact that the artificial mediums at present available for their cultivation are radically different from the tissues and fluids of the body in which they grow and induce disease. The ordinary artificial mediums contain protein degradation products, known as peptone and meat extractives, and little or no unaltered protein. The tissues of the body, on the contrary, contain unaltered protein and little or no peptone.

"A theoretical method of approach to the problem of cultivation of these refractory 'viruses,' therefore, would appear to be the preparation of a sterilizable medium containing unaltered, or nearly unaltered, protein without peptone." Dr. Kendall has prepared such a medium from the intestine of swine by extracting the fat and other substances, leaving a dried residue, composed chiefly of protein that has suffered little change. A suspension of this dried powder in Tyrode's solution, a dilute solution of several salts, and sterilized in an autoclave, constitutes the new K medium.

Dr. Kendall first inoculated several lots of this K medium with blood from cases diagnosed as mild influenza by different physicians in two hospitals. "Three of these cultures, after being incubated for several days, showed increasing cloudiness, indicating growth of micro-organisms." The filter-passing organisms isolated from the blood taken from two of the patients with symptoms of influenza induced fever and paroxysms of violent sneezing or coughing

in rabbits. From the blood of these rabbits, taken on the second day of infection, a filter-passing "virus" was again cultivated in the K medium. From these filterable cultures growing in K medium, a coccus (round, microscopically visible and non-filter-passing microorganisms) was later isolated. This coccus, in its unfilterable state, could readily be retransformed to the filterable state in K medium, refiltered and recovered again in non-filter-passing form. This microbe, therefore, can exist in two forms—a filterable state, in which condition it grows in the K medium, but does not appear to grow visibly in peptone mediums; and a non-filterable state, in which growth upon ordinary peptone-containing mediums is readily obtained. The rabbit infections were induced, while the coccus was apparently in the filterable state. Attempts to induce similar infection with the non-filterable form were unsuccessful.

While the available evidence is suggestive that this coccus, recovered from cultures in K medium of blood from patients suffering from clinical influenza, is the cause of the disease, the most significant result brought to light in this investigation is the obvious existence of the microbe isolated from these three cases in two states, a filterable and a non-filterable. It is a sort of bacteriological Ariel, which, like the Shakespearean sprite, changes its form at the order of its master.

Having shown that this coccus exists in two forms, it was suspected that other bacteria might exhibit this same dual existence, if subjected to the same cultural conditions. Such has proved to be the case. The first microorganism examined for this purpose was a culture of typhoid bacillus which had been in stock on artificial culture mediums in the laboratory for several years. It was found that this bacillus, a rod-shaped organism, can also be rendered filterable. The transformed filterable organisms fail to grow in ordinary artificial mediums, in which they grew luxuriantly before their transformation. From the growth in K medium eventually typical typhoid bacilli may be recovered.

To date, seven different species of bacteria have been transformed from non-filter-passing to filterable and back again to non-filter-passing forms. In their filterable and transition stages these bacteria appear to be more inert than in their typical forms. One or more transfers in ordinary mediums may be required to elicit the usual luxuriance of growth and capacity for chemical activity.

Dr. Kendall has observed the changes which appear to lead to the filterable state actually occurring in the typhoid bacillus in K mediums. After 15 to 18 hours' incubation in this medium, many of the typhoid bacilli lose their normal uniform structure and appear first as faintly discernible shadows, having the bacillary or rod-shaped outline. They actively swim about in the medium at this time. From two to four or more brilliantly luminous, but very tiny granules appear within the shadowy outlined organisms. Finally, the bacillary part of the organism disappears, and there remain merely the minute granules, appearing in a dark field illuminator as intensely bright, yellow oval bodies. These granular vestiges of the typhoid bacillus pass through a stone filter readily. It may be recovered in the bacillary state by appropriate recultivation.

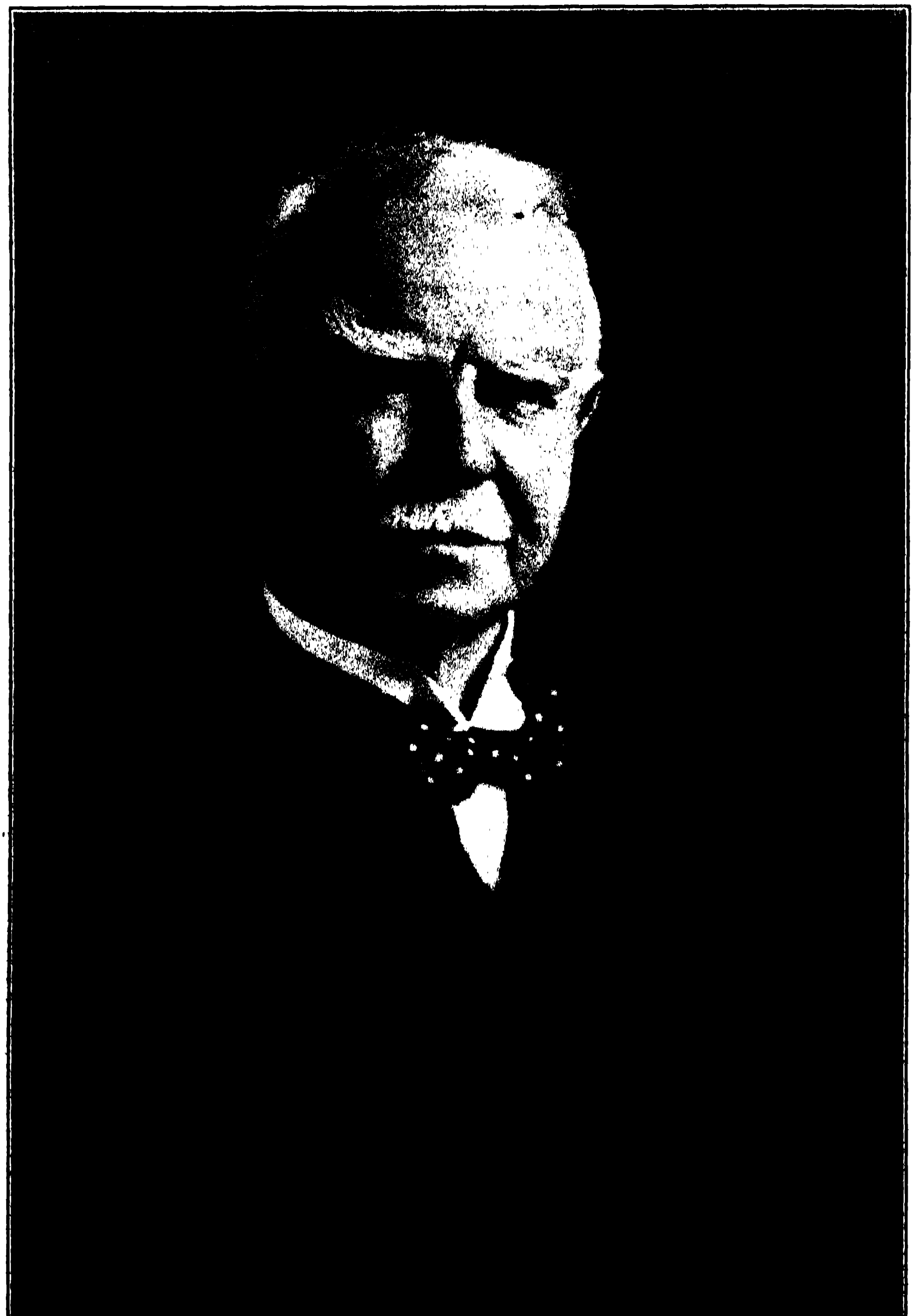
Next, it appeared that the much discussed, and not well understood, bacteriophage which passes readily through stone filters might conceivably have a similar explanation. Filtrates of staphylococcus "phage" have yielded perfectly typical cultures of staphylococcus upon cultivation in the proper manner. This observation will necessitate a reconsider-

ation and possibly a revision of our conception of the nature of the bacteriophage.

The successful use of K medium requires a considerable amount of skill and practice in bacteriologic technique. If properly employed, it will yield positive results in a high percentage of cultures from the blood of patients suffering from a variety of diseases which have hitherto yielded uniformly negative results with other methods.

What is the practical importance of this new culture medium and of the discovery of the dual existence, the "double life," of bacteria? Its full significance is not yet apparent. To learn that ordinary bacteria may change their form as readily and almost as rapidly as old Proteus in Homer's Odyssey will be most disconcerting to bacteriologists, accustomed for a generation to consider species of bacteria at least as stable and as difficultly alterable as species of cats and dogs. Almost as disturbing is the evidence that possibly the mysterious bacteriophage is merely a condition in which bacteria have, so to speak, dived below the surface of visibility, and have suffered a reduction in size as striking as that which befell Alice when she ate the magic cake in Wonderland. Like Alice they can, by proper treatment, be restored from the filterable or "phage" state to their normal size.

Dr. Kendall has supplied an explanation for the hitherto discouragingly uniform failure to isolate the causative microbe of many known infectious diseases and has furnished a workable method of overcoming this difficulty. The use of his new K medium promises to reveal much of academic and practical significance in the private life of bacteria, as well as to furnish a means of discovering the causes of many diseases. When the cause of a disease has been found, medical science has made a long step forward in its control and prevention.



Lafayette, Ltd.

SIR ALFRED EWING

PRESIDENT OF THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

THE PROGRESS OF SCIENCE

THE BRITISH ASSOCIATION AT YORK

For its annual meeting in 1932, following the celebration of its centenary in London in 1931, the British Association returned to York, its birthplace. In a district of such varied interests, from the tranquil antiquity of the city within the walls, to the great centers of industry on the one hand, the classic fields for geology, botany and archeology on the other, which lie within a radius of a few miles, the British Association is really in its element. Whether its officers, academically robed, were accompanying the corporation in state to the Minster on Sunday morning, or whether its engineers (let us say), in far different costume, were descending a coal-mine, or whatever other activities between these extremes its members might undertake, there was the justifiable sense that the association was carrying out that function for which its founders at York in 1831 designed it, "to obtain more general attention for the objects of science."

Appropriately, the president, Sir Alfred Ewing, through his inaugural address, did most to focus that attention. He directed it, under the title of "An Engineer's Outlook," toward recent advances in physics as well as in engineering; he recalled some of those which had been made through the medium of the association itself; and at the close of his address he invited consideration of what is, and what should be, the ethical connotation of some of these achievements. "What is" and "What should be" are, alas, far from synonymous. "The cornucopia of the engineer has been shaken over all the earth, scattering everywhere an endowment of previously unpossessed and unimagined capacities and powers. Beyond question many of these gifts are benefits to man, making life fuller, wider, healthier, richer in comforts and interests and in such happiness as material things can promote. But we are acutely aware that the engineer's gifts have been and may be grievously abused. Man was ethically unprepared for so great a bounty. In the slow evolution of morals he is still unfit for the tremendous responsibility it entails. The command of nature has been put into his hands before he knows how to command himself." Here was a text upon which, in the press, many persons wrote many foolish things, and a few wise ones. They do harm who preached upon this text without attempting to assimilate the lucid address which led up to it, but they do good who follow Sir Alfred Ewing in urging men toward a redress of the balance.

Those who jibe at science for becoming suddenly afraid of its own results might well (if they had the intelligence) have acquainted themselves with the intensely practical applications which were laid before many audiences at this meeting in York. Applied geophysics, stereochemistry, British overseas markets, constructive theories in psychology and sheep farming are a selection of subjects from the addresses of sectional presidents. Discussions on water pollution, railway traction by steam, oil and electric power, the control of humidity in industrial processes, the use of statistics for the business executive and the film in education are examples drawn from various sectional programs, almost at hazard. The two customary "evening discourses" were on plant products of the Empire in relation to human needs,

by Sir Arthur Hill, director of Kew Gardens; and on uses of the photoelectric cell, by Mr. C. C. Paterson, who with the aid of elaborate apparatus and skilled assistants gave the beau ideal of the demonstration-lecture.

It is not, however, to be supposed that pure science has come to take a subordinate position in the programs of the association. There are those who fear such an outcome. To one, however, who, while pretty intimately concerned with these programs, is merely an onlooker at their actual compilation by the sectional committees and the council of the association, it seems that the balance is held with much skill. The men and women of science lay before the public each year certain general topics of wide interest. They also use the occasion of the association's meeting to meet one another and discuss other subjects into which few if any laymen can follow them. It is the function of the association—implicit in that statement of objects which was laid down for it at York in 1831, and remains unaltered in its statutes—to offer occasion for both these forms of activity. So far as concerns its mandate "to promote the intercourse of those who cultivate Science," as the founders phrased it a century ago, the association performs perhaps its very best work when it provides, as no other institution can, a common meeting-ground for those whose scientific activities follow usually divergent directions; as when, at the York meeting, physicists and psychologists met together to discuss the quantitative relation of physical stimuli and sensory events.

The British Association is in the fortunate position that its meetings traditionally receive a very wide press. The presidential address and other salient features of the program obtain almost world-wide publicity by this means. It is true that journalists and scientific men may not always agree as to what constitutes a salient feature; but the association's meetings do introduce a temporary flavor of science into ephemeral literature. But this practice does not in itself provide a sufficiently strong link between science and the public understanding. It is true, again, that many of the papers read at an association meeting are published in specialist journals, and the association makes an attempt to record such publication in its annual report. In that volume the presidential addresses are printed in full, and they are also issued annually under the title of "The Advancement of Science," at the price of three shillings and sixpence. But the association suffers in common with many other scientific societies from an inability, through lack of means and of contact with the ordinary channels of distribution, to report and record at all fully the volume of the spoken words at any given meeting. That volume runs into millions. Moreover, neither the association nor any other body, even if they had the means, would benefit by attempting to make a "corner" in scientific publication. Nevertheless, more effective and wider means of publication of scientific material, adapted to the common understanding, would seem to be one of the practical steps forward from the position which General Smuts, from the chair of the centenary meeting in 1931, outlined in a sequence of ideas not dissimilar from those of Sir Alfred Ewing quoted above. "A serious lag," he said, "has already developed between our rapid scientific advance and our stationary ethical development. . . . Science must itself help to close this dangerous gap."

O. J. R. Howarth,
Secretary

WILLIAM PATTEN

FOR THIRTY-EIGHT YEARS PROFESSOR OF ZOOLOGY AT DARTMOUTH COLLEGE, IN WHOSE DEATH AT THE AGE OF SEVENTY-ONE YEARS ZOOLOGICAL SCIENCE LOSES ONE OF ITS LEADERS. AN ARTICLE BY PROFESSOR PATTEN ON "THE FOUNDATIONS OF THE FACE" WILL BE FOUND IN THE PRESENT ISSUE OF THE SCIENTIFIC MONTHLY. IN THE ILLUSTRATION HE IS SHOWN CHISELING OUT AN OSTRACODERM WHICH HE REGARDED AS THE "CONNECTING LINK" BETWEEN THE VERTEBRATES AND CERTAIN ARACHNOID ANIMALS.

SIR CHARLES SCOTT SHERRINGTON

THE NOBEL PRIZE IN PHYSIOLOGY AND MEDICINE

SIR CHARLES SCOTT SHERRINGTON

In conferring the Nobel Prize jointly upon Sir Charles Scott Sherrington and Edgar Douglas Adrian, the Stockholm committee explained that the award was made in recognition of the epoch-making work of these two investigators in isolating and studying the activities of individual nerve cells ("neurones"). And it might have been pointed out that the quest of the single neurone by the physiologist has had many of the dramatic features associated with the quest by the physicist of the single atom: in both cases the difficulties were exceptionally great and ultimate success depended upon amplification of minute differences of electrical potential and upon the introduction of ingenious devices for automatic recording.

Sherrington's achievement in isolating the single motor neurone represents the culmination of more than forty years' work upon the nervous system, and it is significant that in his earliest investigations (1885–1906) he had sought to interpret the activity of the brain and spinal cord in terms of the anatomical units which Retzius and others were then demonstrating microscopically by the new silver impregnation methods. Although such units continued, until very recently, to elude functional isolation, they served as the basis of all Sherrington's investigations and generalizations, including the reciprocal innervation of antagonistic muscle (1893–1909), localization of function in the motor cortex (1895–1917), levels of nervous integration (1898–1906), the principle of the final common path (1904), the proprioceptive system (1906), the nature of central inhibition (1911–1925) and of postural contraction (1915–1930), and the principle of "recruitment" (1923–1925). Until 1928–1930 the motor neurone remained a convenient anatomical abstraction, defying satisfactory functional isolation. Through a series of notable improvements in the technique of mechanical and electrical recording of reflex responses which began in 1918[1] and continued with a series of collaborators,[2] the response of each successive motor nerve unit in a gradually increasing reflex response has been placed under direct observation. The rate and characteristics of the discharge of individual motor neurones during the knee-jerk, flexor reflex and crossed extensor reflexes thus became known. Furthermore, the exact magnitude of the muscular tension controlled by the activity of each motor fiber has been disclosed by direct observation and by the method of counting motor nerve fibers to a given muscle whose total tension capacity is known. The two methods are in accord and have given this striking information, that a single motor nerve fiber may control as much as 40 to 50 gms of tension.[3] A full account of these investigations is contained in a book by Sherrington and his pupils, published by the Oxford Press a few months ago under the title "Reflex Activity of the Spinal Cord."

In addition to the fundamental disclosures just mentioned, Sherrington has offered a broad conception of the function of the nervous system—the principle "integration," which was first put forward in his Silliman lectures at Yale in 1905. This has now become basic to psychology as well as to neurology and neurophysiology, and it richly justifies the designation applied to Sherrington a year ago, when receiving an honorary degree in Berne, of "the philosopher of the nervous system."

J. F. Fulton

Yale University

1 Dreyer and Sherrington, *Proc. Roy. Soc.*, 90B.

2 Sassa, 1921, Liddell, 1923–1925; Creed, 1928; Cooper and Denny-Brown, 1927; and Eccles, 1929–1930—all in *Proc. Roy. Soc.*

3 J. C. Eccles and C. S. Sherrington, *Proc. Roy. Soc.*, 106B, June, 1930.

J. Russel & Sons

PROFESSOR EDGAR DOUGLAS ADRIAN

PROFESSOR EDGAR DOUGLAS ADRIAN

Edgar Douglas Adrian, who has been awarded the Nobel Prize in Medicine and Physiology in association with Sir Charles Scott Sherrington, is Foulerton professor of the Royal Society and fellow of Trinity College, Cambridge. The award has been made to him in recognition of his brilliant and fundamental discoveries concerning the mechanism of sense organs and motor nerve cells and the nature of nerve messages. Inasmuch as these messages give rise to sensation and effect the control of muscular contractions, their analysis has been of basic importance to the medical and biological sciences and has laid the foundation for far-reaching advances in neurology.

About seven years ago Professor Adrian succeeded in recording for the first time the impulses in single nerve fibers. In order to determine the context of the messages going from the sense organs to the central nervous system he registered the variations in electrical potential which are associated with nervous activity. Initial experiments showed, however, that because the nerve trunks contain large numbers of fibers which are in independent activity it was difficult to follow and to analyze the response of the individual units. In order to overcome this difficulty, he developed a technique which enabled him to cut away all but one of the sense organs connected with the nerve trunk under investigation. It thus became possible to deal with a nerve in which there were impulses coming from a single sense organ. A further difficulty remained, however, for the electrical pulses in this single unit of the nervous system were too small to operate an electrical recorder sufficiently rapid to follow these brief transients. He therefore employed a vacuum tube amplifier to magnify the nerve potentials many thousand times and then transformed them into a moving beam of light recording on a photographic film or into sound issuing from a loud speaker.

By such means he found that the discharge from a sense organ consists of a series of nerve impulses of a definite frequency, which is greater the greater the intensity of the stimulus. Furthermore, as the strength of stimulus is increased more receptors are brought into action. And so he established the fundamental fact that the neural basis for varying intensities of sensation is a variation in the number of impulses going into the central nervous system, as determined by the frequency of the impulses and the number of active units. A continued constant stimulus produces a train of impulses of a decreasing frequency, thereby explaining the subjective phenomenon of adaptation. The messages from a wide variety of sense organs have been investigated and he has shown their fundamental character to be the same, although certain differences in the form of the impulses may play a part in determining differences in the quality of sensation. His studies of impulses in pain fibers are the foundation for a better understanding of one of the most difficult problems in medical science.

How these impulses act upon the central nervous system and interact to produce coordinated muscular activity has been one of Sherrington's major fields of investigation. By recording the motor impulses resulting from such central activity Adrian has given conclusive answers to questions regarding the regulation of muscular contraction. He has found that there is discharged from the cells in the central nervous system to the muscle fibers supplied by a single nerve fiber a series of impulses of a frequency determined by the degree of central excitation. A weak contraction he has shown to be the result of a low frequency of impulses in comparatively few nerve fibers. A strong contraction, on the other hand, is developed as a result of a high frequency of impulses in many fibers.

Although Adrian has already achieved spectacular success in revealing many of the fundamental properties of nervous action, it is fair to say that these advances are only an indication of what may be expected from his remarkable experimental attack. He has developed a method and point of view which is capable of shedding new light on the regulation of a great diversity of bodily functions. Only recently, for instance, he has analyzed the impulses going to the blood vessels over the sympathetic nerve fibers regulating blood pressure.

It is particularly appropriate that the Nobel Prize should be awarded jointly to Sherrington and Adrian. Although they have never worked in collaboration, they are warm friends and have long been intimately associated in the affairs of the Physiological Society and the *Journal of Physiology*. Carried out independently and by different methods, their investigations have in a remarkable way fitted together into a clear and dramatic explanation of the manner in which the nervous system controls the activities of the living organism.

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OUR HEALTH AND SAFETY

THE autumn weeks have seen meetings of several national and regional associations concerned with human health and safety, from both the personal and the community angle.

The American College of Surgeons

DANGER IN DUST

ARTIFICIAL EXPLOSIONS OF VARIOUS INDUSTRIAL AND FOOD DUSTS, UNDER CONDITIONS SIMULATING THOSE OF COMMERCIAL PLANTS, ARE PRODUCED IN THIS LABORATORY AT THE ARLINGTON FARM OF THE U. S. DEPARTMENT OF AGRICULTURE. THE EXPLOSION HERE SHOWN WAS SET OFF DURING THE RECENT SAFETY CONGRESS IN WASHINGTON.

held its twenty-second clinical congress at St. Louis, from October 17 to 21, under the presidency of Dr. J. Bentley Squier, of New York. Dr. Allen B. Kanavel, of Chicago, retiring president, delivered his address on "Intangibles in Surgery." The John B. Murphy Oration in Surgery was delivered by Sir William I. de Courcy Wheeler, of Dublin, on the subject, "Pillars of Surgery." Dr. Robert Andrews Millikan, director of the Norman Bridge Laboratory of Physics, California Institute of Technology, gave a fellowship address on "Some New Things in Physics." The meeting was marked by a number of notable symposia.

The American Public Health Association held its sixty-first annual meeting in Washington, D. C., from October 24 to 27. Included among its sectional sessions were: vital statistics, industrial hygiene, child hygiene, public health education, public health nursing, food and nutrition, epidemiology and many other topics.

Following shortly after the meeting of the Public Health Association, the National Safety Congress and Exposition was held in Washington, from October 3 to 7. A special feature of the meeting was a demonstration of the laboratory for the study of dust explosions at the Arlington farm of the U. S. Department of Agriculture.

A regional conference on social hygiene, sponsored by the Social Hygiene Society of the District of Columbia, was held in Washington, from October 27 to 29. The fifth annual graduate fortnight of the New York Academy of Medicine was held in New York, from October 17 to 28; it was devoted to the general subject "Tumors."

PROTEAN BEHAVIOR OF BACTERIA

WHETHER or not bacteria change their forms through definite life-cycle stages is becoming more and more a moot point among biologists. Very early in the history of bacteriology it became known that at least some species assume distorted shapes in cultures which have been allowed to become too old and to accumulate too high a concentration of katabolic products. The spore-forming ability of many species was also among the first things learned about bacterial physiology.

These form-changes, however, were ascribed to unfavorable environmental conditions, and spore-formation in particular was considered to be definitely adaptational. The question still remained whether these minutest of living things passed through changes analogous to the astonishing metamorphoses observed in many protozoa, or to the larva-pupa-adult phases of some insects.

Much experimentation was devoted to this question, largely by means of modifying the nutrient media in which bacterial cultures are grown. Important pioneer work was done in this field by Dr. Philip Hadley, of the University of Michigan. Following the lead of the now famous d'Herelle experiments that brought about the discovery of bacteriophage, Dr. Hadley was able to produce filter-passing phases of ordinary bacteria by suitable culturing. Even more sensational was the announcement in the summer of 1931 by Dr. Arthur I. Kendall, of Northwestern University, that with his special "K" medium he could at will reverse filterable and visible phases of many species, produce visible phases from pathogenes hitherto known only as filter-passers, and apparently even regenerate staphylococci out of the bacteriophage that had "destroyed" them.

These discoveries, and others like them, tended to support the theory that all the filtrable viruses are "alive," and even that they may all have visible

phases, awaiting only proper culturing to be demonstrated. But this theory has received a sharp setback from the work of Dr. Carl G. Vinson, formerly of the Boyce Thompson Institute for Plant Research and now at the University of Missouri. Dr. Vinson has succeeded in obtaining the virus of tobacco mosaic in nearly pure crystalline form, with indications that it is a non-living proteinaceous substance, more or less analogous to an enzyme in its make-up and action. Presumably other filterable viruses, at least those of the other mosaics and related plant diseases, resemble the one investigated by Dr. Vinson.

In the meantime, the debate over the reality of life cycles in bacteria continues, with evidence advanced on both sides. Miss Alice C. Evans, senior bacteriologist of the U. S. Public Health Service, has found that the causal organism of encephalitis lethargica, the so-called European sleeping sickness, which is normally a coccus, at times assumes a rod-shaped form, and occasionally becomes a filter-passer as well. This discovery is of immediate diagnostic value as well as of theoretic importance, because hitherto the presence of rod-shaped bacilli in a culture of coccoid forms was naturally taken as a sign of contamination. Now they may signify not a mixed culture but a metamorphosing one.

Dr. Ralph G. Wyckoff, of the Rockefeller Institute for Medical Research, holds that bacterial life cycles have no real existence. He followed the development of bacteria for a total of 600 hours with a specially constructed micro-motion camera, tracing their changes as their nutrient media and other environmental factors were changed. The organisms always tended to resume their normal form when restored to normal conditions, he stated. Likewise, he does not think that the germs have a filterable phase distinct from their normal one. His studies led him to the opinion that the change in food and environmental factors enables the organisms to pass through filters, not by changing their forms but by another process which may, for instance, make them more slippery or more compressible. Dr. Kendall's "K" medium, he pointed out, has been found to aid the passage of normal bacteria through fine filters.

Support for Dr. Wyckoff's point of view can be found in the results obtained at the Mayo Clinic by Dr. Edward C. Rosenow. He was able to detect coccoid and diplococcoid organisms in filtrates of poliomyelitis and herpes encephalitis viruses, by the use of the remarkable microscope invented by Dr. Royal Raymond Rife, of San Diego. He also confirmed the findings of Dr. Kendall, who had seen small, active, oval bodies, turquoise-blue in color, in the filtrable phase of typhoid bacilli.

Another aspect of the Proteus-like behavior of bacilli has been developed by Miss Agnes Quirk, of the U. S. Department of Agriculture. She was concerned primarily with the colony-form rather than with the form of the individual organism. The two bacteria species causing potato black rot and plant tumor form two types of colony, "rough" and "smooth," when cultured on solid media. Though they are microscopically indistinguishable, the species had been provisionally regarded as being divided into separate strains. Miss Quirk has shown that either type of colony can be produced at will by suitable manipulation of the hydrogen ion concentration in the medium. She has extended her work to thirteen plant pathogens; and Major James S. Simmons, of Walter Reed Hospital, has used the same technique with success on a strain of typhoid bacilli. Miss Quirk has also been able to produce filtrable phases of her bacteria.

FRANK THONE

SCIENCE SERVICE

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